SHOUT
SHARE
IT

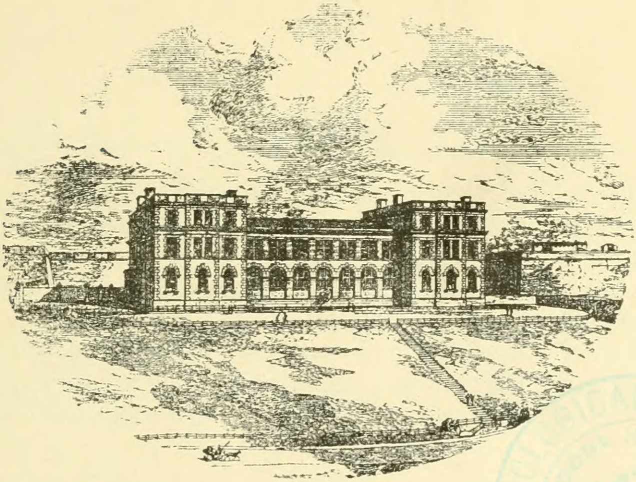
Journal

OF THE

MARINE BIOLOGICAL ASSOCIATION

OF

THE UNITED KINGDOM.



MARINE BIOLOGICAL LABORATORY
LIBRARY
WOODS HOLE, MASS.

VOLUME XI (N.S.).
1916-18.

14976

PLYMOUTH:
PUBLISHED BY THE ASSOCIATION.

5470

The Council of the Marine Biological Association wish it to be understood that they do not accept responsibility for the accuracy of statements published in this Journal, excepting when those statements are contained in an official report of the Council.

ERRATA.

Page 14, line 2. For "1·20 mm." read "1·4 mm."

Pages 240–241, Tables XXXVI and XXXVII. The records in these two tables should be added to those of Table XXXV as Gobius sp.

Page 289. In the second square of the last row of the square diagram for "c" read "C."

Page 291, line 3. Insert the word "coloured" before the word "offspring."

" " 13. For "all black offspring" read "no red offspring."

Page 317, line 6. For "36·6" read "32·6." For "12·2" read "16·3."

CONTENTS OF VOLUME XI.

(NEW SERIES.)

PAGE

List of Governors, Founders, and Members—
May, 1917 266

Report of the Council—
1915 259
1916 425
1917 519
Balance Sheet, 1915 264
ditto 1916 425
ditto 1917 524

Allen, E. J.
Post-Larval Teleosteans collected near Plymouth during the Summer of 1914 207
Heredity in Plants, Animals, and Man 354
Food from the Sea 380
The Age of Fishes and the Rate at which they Grow . . . 399

Allen, E. J., and Sexton, E. W.
The Loss of the Eye-pigment in *Gammarus chevreuxi*. A Mendelian Study 273

Cutler, D. Ward.
A Preliminary Account of the Production of Annual Rings in the Scales of Plaice and Flounders 470

Flattely, F. W.
Notes on the Œcology of *Cirratulus* (*Audouinia*) *tentaculatus* (Montagu) . 60

Keys, J. A.
A List of Maritime, Sub-Maritime, and Coast-frequenting Coleoptera of South Devon and South Cornwall, with especial reference to the Plymouth District 497

Lebour, Marie V.
Stages in the Life History of *Calanus finmarchicus* (Gunnerus) Experimentally reared by Mr. L. R. Crawshay in the Plymouth Laboratory 1
Notes on the Life History of *Anaphia petiolata* (Kröyer) . . . 51
Medusæ as Hosts for Larval Trematodes 57
The Microplankton of Plymouth Sound from the Region beyond the Breakwater 133
The Peridiniales of Plymouth Sound from the Region beyond the Breakwater 183

LEBOUR, MARIE V. (*continued*). PAGE
Some Parasites of *Sagitta bipunctata* 201
The Food of Post-Larval Fish 433
A Trematode Larva from *Buccinum undatum* and Notes on Trematodes from Post-Larval Fish 514

MATTHEWS, DONALD J.
On the Amount of Phosphoric Acid in the Sea-water off Plymouth Sound 122, 251

ORTON, J. H.
An Account of the Researches on Races of Herrings carried out by the Marine Biological Association at Plymouth, 1914–15 . . . 71

SEXTON, E. W., AND WING, M. B.
Experiments on the Mendelian Inheritance of Eye-colour in the Amphipod *Gammarus chevreuxi* 18
See also ALLEN, E. J., and SEXTON, E. W.

Abstract of Memoir recording Work done at the Plymouth Laboratory—
The Development of *Alcyonium digitatum*, with some Notes on the Early Colony Formation. By Annie Matthews 258
In Memoriam : H. C. Dannevig 131

Stages in the Life History of *Calanus finmarchicus* (Gunnerus), Experimentally Reared by Mr. L. R. Crawshay in the Plymouth Laboratory.

By

Marie V. Lebour, M.Sc.,

Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist in the Plymouth Laboratory.

With Plates 1 to 5 in the Text.

[The stages in the development of *Calanus finmarchicus* described and figured by Miss Lebour in the present paper were taken from culture jars given into my charge by Mr. L. R. Crawshay, when he left the Laboratory to undertake military duties in connection with the war. In one jar at that time the first copepodid stage, from eggs laid in the jar, had just been reached, and the technical details for the successful rearing of the animals had been mastered. The experiments had been conducted with great care, and all possible precautions had been taken to prevent contamination. Subsequently the experiments were repeated up to a certain point by myself and some additional stages obtained to complete the series.

The cultures were made in 2-litre glass beakers, containing " outside " sea-water filtered through a Berkefeld filter. In order to secure an even temperature the beakers stood in the circulating water of the Laboratory tanks, and a pure culture of the diatom *Nitzschia closterium* was used as food.—E. J. Allen.]

All the 5 copepodid stages (the 6th being the fully formed copepod) and 5 out of the 6 nauplius stages were found. Unfortunately the 6th nauplius stage was missed and could not be found in the material, but it is described and well figured by Grobben (1903), and his figures and description show that it is very like the same stage of Pseudocalanus and Paracalanus described by Oberg (1906). The latter author's descriptions agree very closely with all the corresponding stages of *Calanus finmarchicus*, the size in all cases being the chief difference. In the very young nauplius stage the feelers differ in being long and thin in *Calanus finmarchicus* and short and hook-like in *Pseudocalanus elongatus.*

Nauplius Stage III is much the commonest stage and occurred all the time the material was being examined. The animal probably stays some time in this stage.

The number of bristles on the antennules of the nauplius is a sure guide to the stage, as they are constant and very easily seen. They also agree exactly in number with similar stages in Pseudocalanus and Paracalanus.

The colouring was much the same throughout all the stages, although not so marked in the early nauplius. The first nauplius stage has pigment present only in the region of the alimentary canal, where a few orange and red spots occur, and the tips of the appendages are a light orange. Later on the colouring is more marked. In the first copepodid stages and after the antennules are beautifully spotted with dark red, the bristles being red, and the furcal bristles are red merging into orange ; the tips of the antennæ and mandibles are red, and the distal portions of all the appendages as far as the maxillipeds and also the hind end of the body are yellow. This colouring appears in all the copepodid stages with slight variations.

Grobben's descriptions agree well with the present material. Those stages which he figures are probably I, III, IV or V, and VI, also the first copepodid stage.

THE NAUPLIUS.

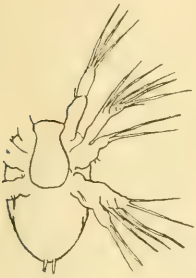
Stage I (Plate 1, Fig. 1). Only one specimen. This is very like Grobben's figure of the early nauplius, but he figures only 2 bristles on the antennule where the present specimen has 3. It appears to be an earlier stage than any of Oberg's. His Stage I of Pseudocalanus agrees with Stage II of the present species. His Stages III–V agree with the corresponding stages of Calanus as described in the present paper. Length of body 0·21 mm., oval, slightly more pointed posteriorly than anteriorly, faintly pink with orange tips to the appendages. Eye dark red. A pair of thin feelers at the hind end of the body.

Appendage I. Antennule (Plate 2, Fig. 1). The end segment divided off, the other 2 merely indicated. A small bristle just behind the end segment, the latter bearing 3 bristles.

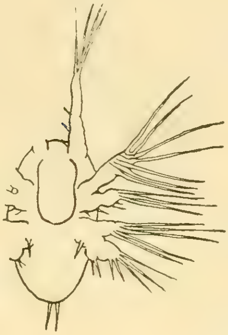
Appendage II. Antenna (Plate 2, Fig. 6).

Coxopodite with a large thorn-like masticatory process.

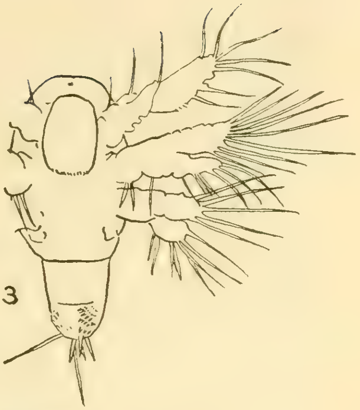
Basipodite with 2 roundish prominences, the proximal portion with 2 small bristles.



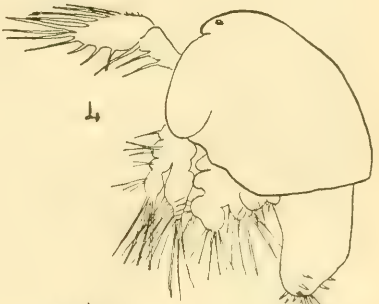
1



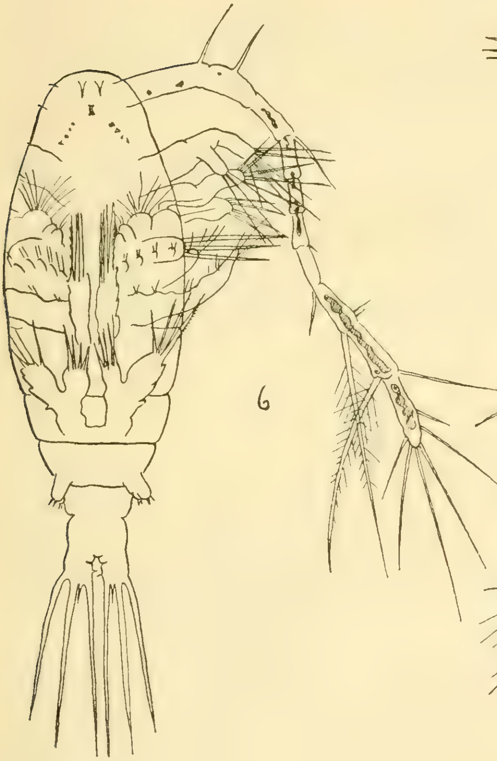
2



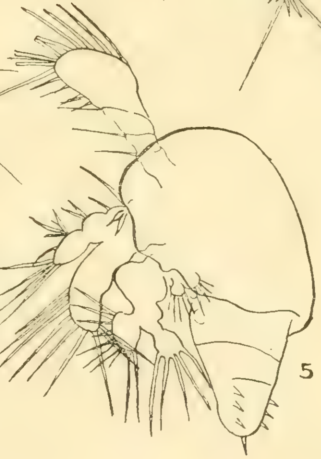
3



4



6



5

M.V.L. del.

Endopodite with 2 long bristles at the end.

Exopodite with 6 segments, the 7th showing under the skin, 1st segment short with no bristle, 2–5 with one bristle each, 6 with 2 bristles.

Appendage III. MANDIBLE (Plate 2, Fig. 11).

Coxopodite with a small bristle.

Basipodite with a large blade and 2 small bristles.

Endopodite with 2 segments indicated, 1st with 2 small bristles and a third showing under the skin; the end segment with 2 long bristles.

Exopodite with 4 imperfect segments, 1–3 with one bristle each, 4 with one long and one short bristle.

STAGE II (Plate 1, Fig. 2). Two specimens. Length of body 0·27 mm., oval, transparent, the same colouring as in I. Hind feelers longer than in I, body bent slightly dorso-ventrally.

Appendage I. ANTENNULE (Plate 2, Fig. 2) with 3 segments, the 1st with no bristle, the 2nd imperfectly divided into 3, each portion with a small bristle; the end segment with 3 long bristles and an accessory bristle; a group of minute spines dorsally.

Appendage II. ANTENNA (Plate 2, Fig. 7).

Coxopodite with a large thorn-like masticatory process and a small bristle.

Basipodite with a masticatory process and 2 lobes each with a small bristle.

Endopodite with a pair of small bristles and at the end 3 long bristles.

Exopodite with 7 segments, 1st short with no bristle, 2–6 with one bristle each, 7 with 2 bristles.

Appendage III. MANDIBLE (Plate 2, Fig. 12).

Coxopodite with a small bristle.

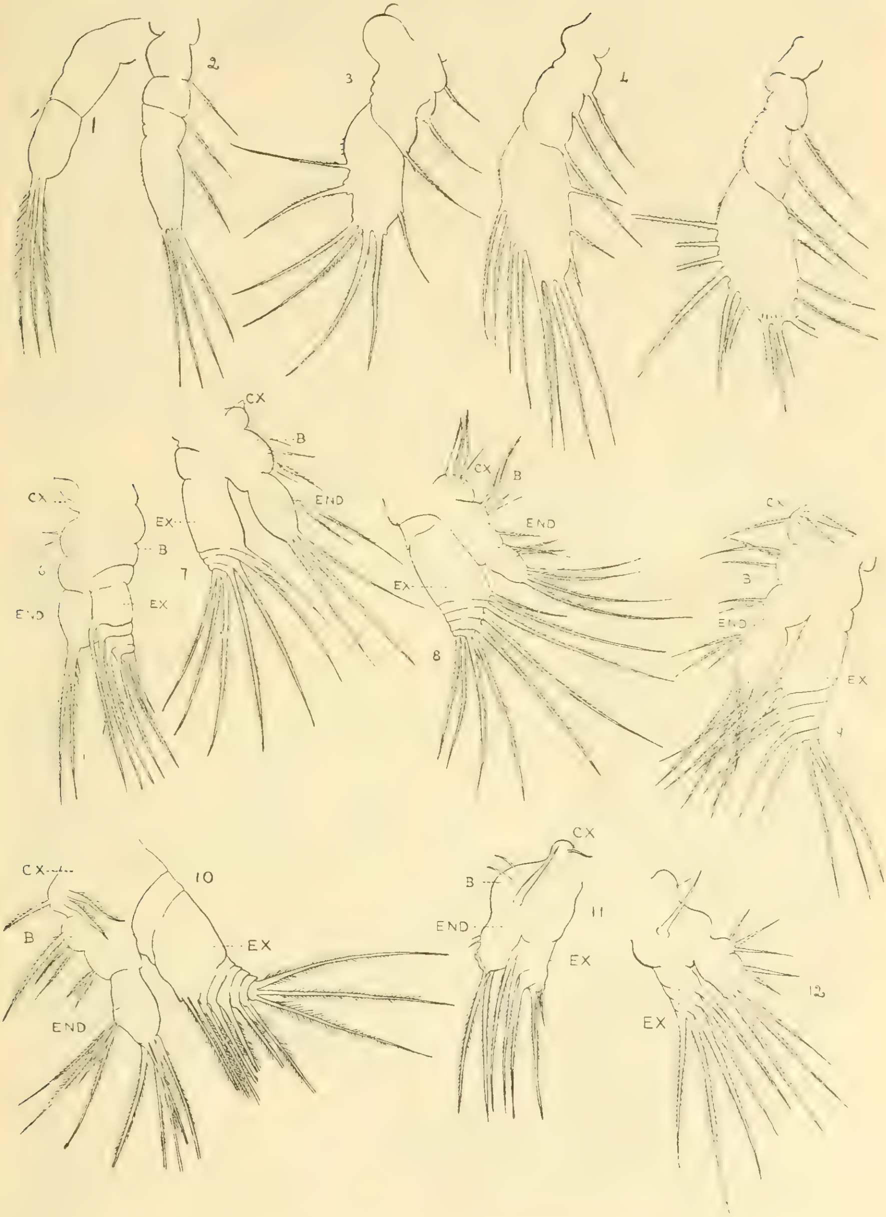
Basipodite with a large blade.

Endopodite with 2 segments indicated, 1st with 3 small bristles, 2 with 2 small bristles, and 3 long bristles at the end.

Exopodite with 4 segments indicated, 1–3 with one bristle each, 4 with 2 bristles.

STAGE III (Plate 1, Fig. 3). Several specimens. Length of body 0·42 mm., the hind end well marked off from the front, body much flexed dorso-ventrally, transparent, coloured rather more strongly than in the first two stages. Hind end of body armed with 2 long feelers, one dorsal and one ventral, a pair of lateral and a pair of posterior hooks. Near the hooks are 3 rows of very short, sharp spines and the same sort of spines surround the bases of the hooks. Besides the 3 pairs of appendages there is a slight indication of a 4th (maxillule).

M. V. LEBOUR. CALANUS FINMARCHICUS. PLATE 2.


1
2
3
4
CX
B
END
EX
6
7
8
9
10
11
12

M. V. L. DEL.

Appendage I. ANTENNULE (Plate 2, Fig. 3). With 3 segments, no bristle on the first segment, second imperfectly divided into 3, each with a bristle, the end segment with 2 small bristles dorsally, one ventrally, and 3 long bristles and an accessory bristle at the end. The group of small hooks are present dorsally as in II.

Appendage II. ANTENNA (Plate 2, Fig. 8).

Coxopodite with 2 large masticatory processes and a small bristle.

Basipodite with 2 imperfectly divided segments, the proximal with a long, straight masticatory process and 2 small bristles, the distal with one small bristle.

Endopodite with 2 imperfectly divided segments, the proximal with 3 small bristles, one smaller than the others, the distal with 3 large and one accessory bristle at the end.

Exopodite with 7 segments, the 1st with no bristle, 2 with one large and one small bristle, 3–5 with one bristle each, 6–7 with 2 bristles each.

Appendage III. MANDIBLE (Plate 3, Fig. 1).

Coxopodite with a large process and a small bristle.

Basipodite with a broad blade and 2 small bristles.

Endopodite with 2 imperfectly divided segments, the proximal with 2 pairs of bristles and a masticatory process, the distal with 2 pairs of small bristles and 2 long end bristles.

Exopodite with 4 segments, 1st with 2 bristles, 2–3 with one bristle each, 4 with 2 bristles.

The 4th appendage is very feebly represented by a faint prominence behind the mandible.

STAGE IV (Plate 1, Fig. 4). 2 specimens. Length of body 0·48 mm. The same shape and colouring as III. Hind end of the body armed with 2 long feelers, 3 pairs of lateral hooks, one pair of end hooks, and 2 pairs of ventral hooks. Small hooks as in III.

Appendage I. ANTENNULE (Plate 2, Fig. 4). With 3 segments. No bristle on the 1st segment, 2 incompletely divided into 3 each with a bristle, terminal segment with 3 ventral bristles, 4 dorsal bristles, and 3 long bristles and an accessory bristle at the end. Small dorsal hooks as in II and III.

Appendage II. ANTENNA (Plate 2, Fig. 9).

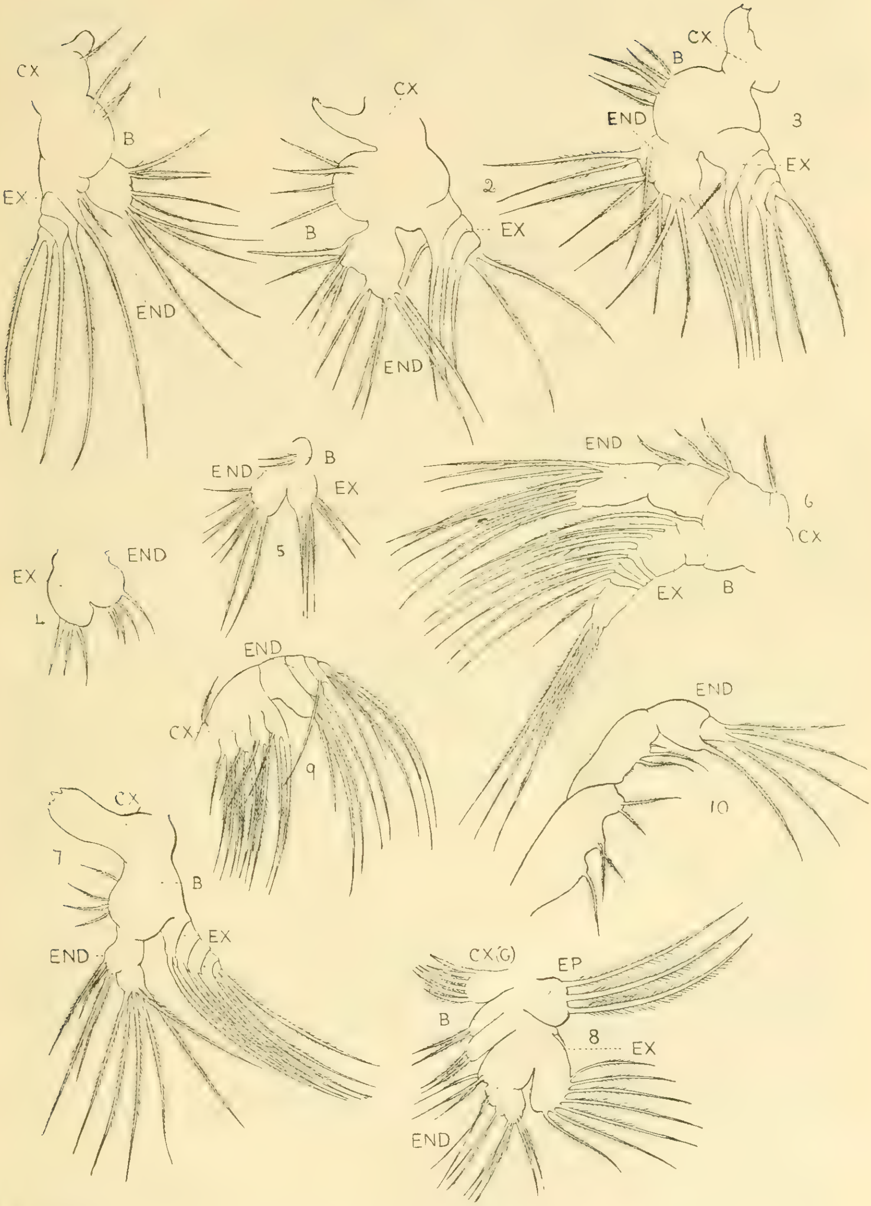
Coxopodite, basipodite and endopodite as in III.

Exopodite with 7 segments, 1st with no bristle, 2 with 3 bristles, 3–7 with one bristle each, 7 with 3 bristles.

Appendage III. MANDIBLE (Plate 3, Fig. 2).

Coxopodite with a well-developed toothed process like the adult but with fewer teeth.

M. V. Lebour. Calanus finmarchicus. Plate 3.


CX
B
EX
END
CX
2
EX
B
END
CX
B
END
3
EX
END
B
EX
5
EX
END
4
END
6
CX
EX
B
END
CX
9
END
10
CX
7
B
END
EX
CX(G)
EP
B
8
EX
END

M. V. L. del.

Basipodite with a large blade and 3 small bristles.

Endopodite with 2 lobes, the inner lobe with 4 bristles and a small masticatory process, the outer lobe with 6 bristles.

Exopodite with 4 segments, the 1st with one large and one small bristle, 2–3 with one bristle each, 3 with 2 bristles.

Appendage IV. MAXILLULE (Plate 3, Fig. 4) small with 2 lobes.

Endopodite with 4 small bristles.

Exopodite with 3 small bristles.

STAGE V (Plate 1, Fig. 5). This specimen, the only one of its kind found, was unfortunately dead and damaged. Length of body 0·51 mm. Much like Stage IV. The hind part of the body divided into 2 segments with indications of a third, and besides Appendage IV there are traces of V and VI, which show as minute knobs. The armature of the hind end was damaged, but 3 pairs of lateral hooks could be seen, so that there are almost certainly 2 end feelers, a pair of end hooks and 2 pairs of ventral hooks, corresponding to the same stage in Pseudocalanus.

Appendage I. ANTENNULE (Plate 2, Fig. 5) with 3 segments, the 1st with no bristle, 2 imperfectly divided into 3 each with a bristle, the terminal segment with one proximal and 2 distal bristles on the ventral border, 6 bristles and a group of small hooks on the dorsal border, and 3 long bristles and an accessory bristle at the end. A row of minute hooks occur inside the tip of the terminal segment.

Appendage II. ANTENNA (Plate 2, Fig. 10).

Coxopodite and basipodite as in III and IV.

Endopodite as in IV, but with 4 bristles on the inner side and 5 end bristles.

Exopodite as in IV.

Appendage III. MANDIBLE (Plate 3, Fig. 3).

Coxopodite as in IV.

Basipodite with one strong and 4 small bristles.

Endopodite, the inner segment with 2 pairs of bristles and a masticatory bristle, the outer segment with 2 pairs of bristles and 2 long end bristles.

Exopodite as in IV.

Appendage IV. MAXILLULE (Plate 3, Fig. 5). Not well seen, as it was somewhat injured.

Basipodite with 2 small bristles.

Endopodite with 6 small bristles and 2 long end bristles.

Exopodite with 2 short bristles and 3 long end bristles.

STAGE VI. Not seen. Grobben gives a good figure of this stage, which is very like the description and figure of Pseudocalanus by Oberg. The rather long body is armed at the hind end with 4 pairs of lateral hooks, 2 feelers, 2 end hooks, and 2 pairs of ventral hooks. The maxillæ and maxillipeds are well developed and swimming feet I and II are present as bilobed structures.

This is the last nauplius stage.

COPEPODID STAGES.

There are 5 copepodid stages before the animal is fully formed. These were recognised by Gran (1902), who gives 6 stages, the last being the mature Calanus. All the 5 stages occurred and were taken from experimental jars started on March 30th, 1915. Nauplii first appeared between the 17th and 24th of April, and on May 19th Stage V was taken from the jar, having taken certainly less than two months to grow from the egg to this stage.

The species can be recognised from the first copepodid stage by the 2 long sensory bristles on the penultimate segments of the antennules. The rostral processes are distinct even in the first stage, which, according to Oberg, is not the case with Pseudocalanus, where they appear only in the second stage.

STAGE I (Plate 1, Fig. 6, and Plate 4, Fig. 1). Length of body 0·80 mm. Three free thoracic segments and urosome of one segment with an anterior constriction. In shape like the adult, but broader in comparison with its length. Caudal furca like the adult, but with 3 long bristles and one short bristle, besides a short inner bristle each side. The antennules are now long like the adult, and usually held out almost at right angles to the body. Colour pale yellow all round the edges of the body, antennules, antennæ, mandibles, part of maxillule, maxilliped, and caudal furca, the tips of all these appendages changing from yellow to red as the extremities are reached. Red pigment occurs all along the antennules, the 3 end segments being almost completely red, and dark red blotches run from the base to about the centre. Traces of red pigment are to be seen in the anterior part of the body. Eye dark red. Rostral processes present. There are 2 pairs of well-developed swimming feet and one rudimentary pair. All the other appendages are well developed.

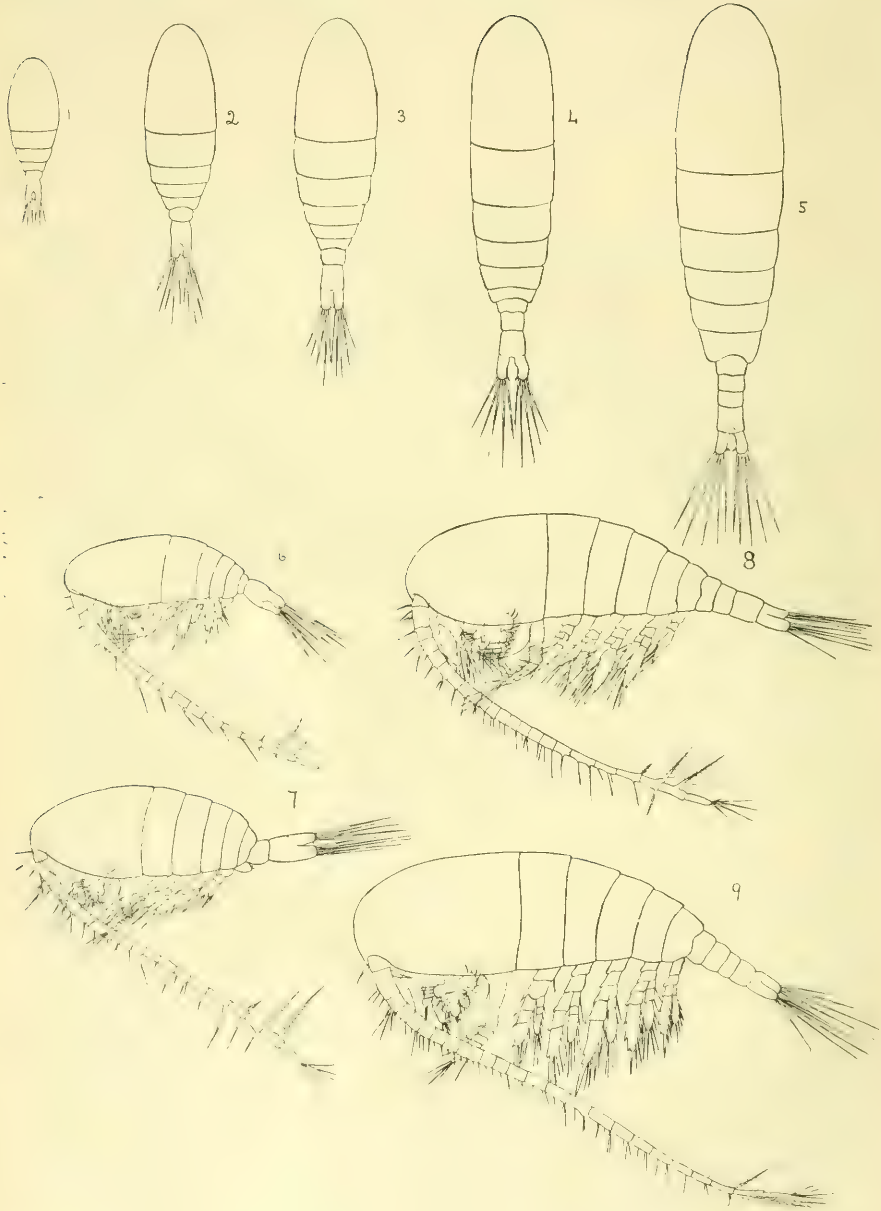
Appendage I. ANTENNULE 10 jointed, long, red sensory bristles, one on the antepenultimate and one on the penultimate segment.

Appendage II. ANTENNA (Plate 3, Fig. 6).

Coxopodite very small with one bristle.

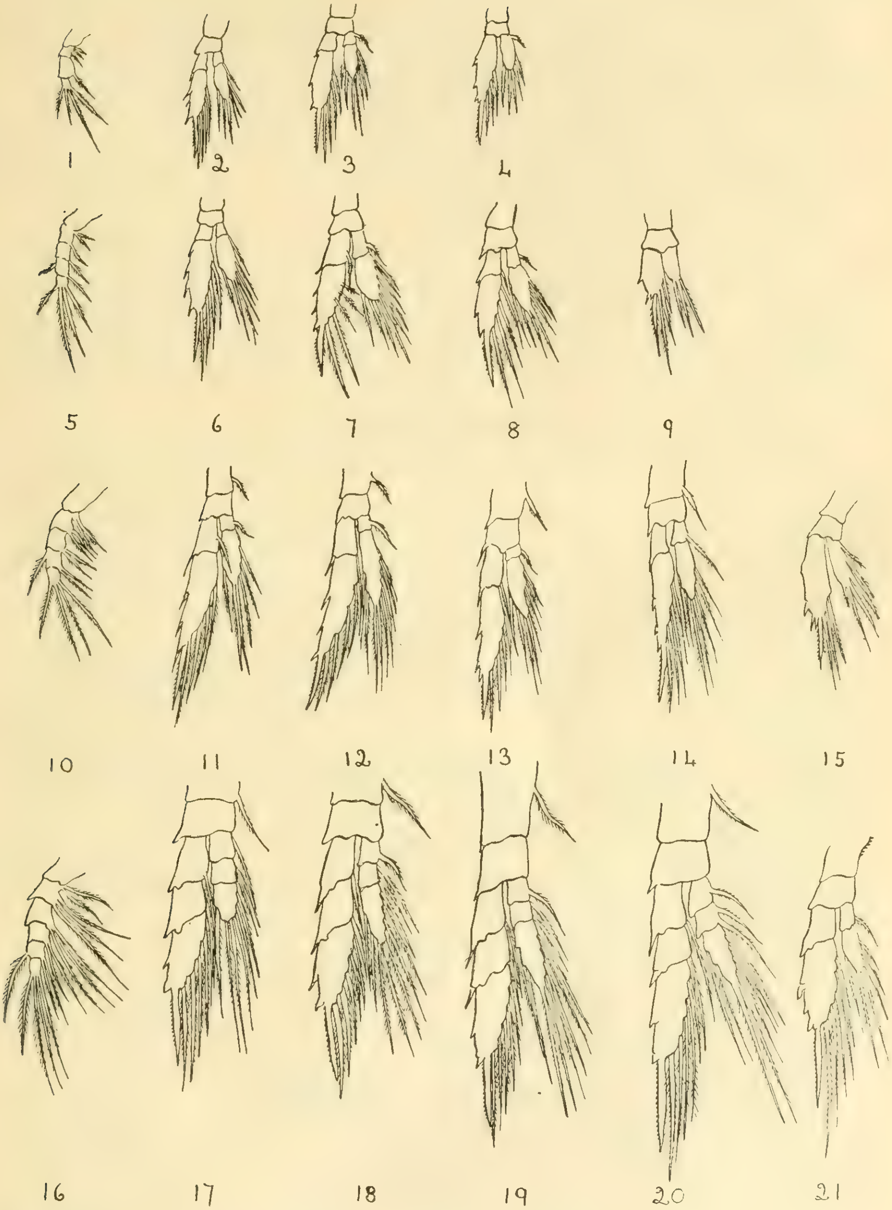
Basipodite, the masticatory bristle has disappeared. 2 bristles present.

M. V. LEBOUR. CALANUS FINMARCHICUS. PLATE 4.



M.V.L. DEL.

M. V. LEBOUR. CALANUS FINMARCHICUS. PLATE 5.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

M.V.L. DEL.

Endopodite with 2 segments, 1st with 2 bristles, 2 with 4 lateral bristles and 5 end bristles.

Exopodite with 7 segments, 7th as long as the 2nd, 1st with one bristle, 2 with 3, 4–6 with one each, 7 with 3 and one very small bristle.

The antenna is now very like the adult, except for the number of bristles on the endopodite, the full number not yet being formed.

Appendage III. MANDIBLE (Plate 3, Fig. 7).

Coxopodite with a conspicuous toothed process.

Basipodite with 4 very weak bristles.

Endopodite with 4 bristles on the proximal portion, 6 bristles at the end.

Exopodite with 5 segments, 1–4 with one bristle, 5 with 2 bristles.

Much like the adult mandible, but without the full number of bristles on the endopodite.

Appendage IV. MAXILLULE (Plate 3, Fig. 8).

Coxopodite with a large lobe, the gnathobase, armed with 6 spiky eating bristles.

Basipodite with 3 lobes, 2 lobes on its inner margin each with 2 short bristles, and a large lobe on its outer margin, the epipodite, armed with 3 long and stout bristles with red tips. Between the epipodite and the exopodite is a very small lobe with a small bristle.

Endopodite, the proximal lobe with 3 bristles, the end lobe divided into 4 portions, 1st with 2 bristles, 2 with 2, 3 with 3, and 4 with 2 bristles.

Exopodite with 7 bristles.

This has all the parts of the adult maxillule, but not the full number of bristles on the basipodite, endopodite, and exopodite.

Appendage V. MAXILLA (Plate 3, Fig. 9).

Coxopodite with 4 segments, 1st with 3 long and one short bristle, 2–4 with 2 long and one short bristle.

Basipodite with 2 long and one short bristle.

Endopodite with 3 segments, 1st with one long bristle, 2–3 with 2 long and one short bristle each.

Now the same as the adult maxilla.

Appendage VI. MAXILLIPED (Plate 3, Fig. 10).

Coxopodite of 3 parts, 1st with one bristle, the other 2 with 2 short bristles each.

Basipodite with 2 short and one very short bristle.

Endopodite with 2 segments, 1st with one bristle, 2nd with 4 bristles.

Appendage VII. 1ST SWIMMING FOOT.

Coxopodite and *basipodite* with no bristles.

Endopodite unsegmented, with 4 long bristles.

Exopodite unsegmented, with 4 thorns on the outer margin, a terminal blade, and 3 bristles inside.

Appendage VIII. 2ND SWIMMING FOOT. Like the first, but with one more bristle on the inside of the endopodite. The exopodite has 4 thorns outside and a terminal bristle, with 3 bristles inside.

Appendage IX. 3RD SWIMMING FOOT with 2 lobes, each lobe with 2 hooks at the end.

STAGE II (Plate 4, Figs. 2 and 6).

Length of body 1·20 mm., 4 free thoracic segments, urosome of 2 segments. Caudal furca like the adult, with 5 bristles and a small lateral inner bristle. Colouring the same as I, but slightly lighter. 3 pairs of swimming feet and the rudiments of a 4th pair.

Appendage I. ANTENNULE with 12 segments, the last 7 the same as I.

Appendage II. ANTENNA the same as I.

Appendage III. MANDIBLE the same as I.

Appendage IV. MAXILLULE the same as I, but with 7 bristles on the epipodite.

Appendage V. MAXILLA the same as I.

Appendage VI. MAXILLIPED (Plate 5, Fig. 1).

Endopodite with a 3rd segment, 1st segment with one broad and 2 small bristles, other segments as in I.

Appendage VII. 1ST SWIMMING FOOT (Plate 5, Fig. 2).

Endopodite with 2 segments, no bristle on 1st segment, 2 with 2 long bristles on the outside, one terminal bristle, and 4 bristles inside.

Exopodite with 2 segments, a thorn on the outside of the first, 2 thorns on the outside of the 2nd, a terminal blade, and 4 long bristles inside.

Appendage VIII. 2ND SWIMMING FOOT (Plate 5, Fig. 3).

Endopodite with 2 segments, 1st with one bristle, 2nd with 4 bristles inside, a terminal bristle, and 2 bristles outside.

Exopodite with 2 segments, 1st with a thorn, 2nd with 3 thorns outside, a terminal blade, and 4 bristles inside.

Appendage IX. 3RD SWIMMING FOOT (Plate 5, Fig. 4).

Endopodite unsegmented, one proximal and 3 distal bristles inside, a terminal bristle, and one bristle outside.

Exopodite unsegmented, 3 thorns outside, a terminal blade, and 3 bristles inside.

Appendage X. 4TH SWIMMING FOOT with 2 lobes each with 2 hooks.

STAGE III (Plate 4, Figs. 3 and 7). Like Stage II in colouring. Body more elongated. Length 1·20 mm., 5 free thoracic segments. Urosome of 2 segments. All 5 swimming feet present, the 5th rudimentary.

Appendage I. ANTENNULE with 16 segments, otherwise like II.

Appendage II. ANTENNA like I and II, but with 6 bristles on the inner part of the endopodite.

Appendage III. MANDIBLE like I and II, but with 8 bristles at the end of the exopodite.

Appendage IV. MAXILLULE.

Coxopodite with the gnathobase bearing 8 bristles.

Basipodite like I and II, but with 3 bristles on the proximal lobe.

Endopodite like I and II, but with 4 bristles on the first lobe and 10 on the end lobe.

Appendage V. MAXILLA like adult.

Appendage VI. MAXILLIPED (Plate 5, Fig. 5).

Endopodite of 4 segments, 1st with 3 bristles, 2 with one, 3 with one and a small outer bristle, 4 with 4 bristles at the end.

Appendage VII. 1ST SWIMMING FOOT (Plate 5, Fig. 6).

Endopodite with 2 segments, distal segment with 4 bristles inside, 2 terminal bristles, and one bristle outside.

Exopodite with 2 segments, distal segment with 4 bristles inside, a terminal blade, and 4 thorns outside.

Appendage VIII. 2ND SWIMMING FOOT (Plate 5, Fig. 7).

Endopodite with 2 segments, proximal segment with one bristle inside, distal segment with 5 bristles inside, 2 terminal bristles, and 2 bristles outside.

Exopodite with 2 segments, one bristle on the proximal segment inside and a thorn outside, 5 bristles on the distal segment inside, a terminal blade, and 3 thorns outside.

Appendage IX. 3RD SWIMMING FOOT (Plate 5, Fig. 8).

Endopodite with 2 segments, one bristle on the proximal segment inside, distal segment with 3 bristles inside, 2 terminal bristles, and 2 bristles outside.

Exopodite with 2 segments, the proximal segment with one bristle inside and a thorn outside, the distal segment with 4 bristles inside, a terminal blade, and 2 thorns outside.

Appendage X. 4TH SWIMMING FOOT (Plate 5, Fig. 9).

Endopodite unsegmented, with 3 bristles.

Exopodite unsegmented, with 3 bristles inside, a terminal blade, and 3 thorns outside.

Appendage XI. 5th Swimming Foot 2-lobed, each lobe with 2 hooks.

Stage IV (Plate 4, Figs. 4 and 8). Very like III. Thorax with 5 free segments each with a well-developed swimming foot. Urosome of 3 segments.

Appendage I. Antennule with 23 segments.

Appendage II. Antenna like I, but with 7 bristles on the inner lobe of the endopodite. Very like the adult.

Appendage III. Mandible like I–III.

Appendage IV. Maxillule like I–III, but the epipodite is larger with 9 bristles now like the adult, the 1st inner lobe of the basipodite has 3 bristles like the adult, endopodite with 5 bristles at the end.

Appendage V. Maxilla like the adult.

Appendage VI. Maxilliped (Plate 5, Fig. 10).
Endopodite of 4 segments, 1st with 4 bristles, 2 with 2, 3 with 2 inside and one outside, terminal segment with 4 bristles.

Appendage VII. 1st Swimming Foot (Plate 5, Fig. 11). The proximal joint of the basipodite with an inside bristle.
Endopodite with 2 segments, the proximal segment with an inside bristle, the distal segment with 3 inside bristles, 2 terminal bristles, and one outside bristle.
Exopodite with 2 segments, the proximal segment with an inside bristle and an outside thorn, the distal segment with 4 bristles inside, a terminal blade, and 3 thorns outside.

Appendage VIII. 2nd Swimming Foot (Plate 5, Fig. 12).
The proximal segment of the basipodite with an inside bristle, the distal segment with an outside thorn.
Endopodite with 2 segments, the proximal segment with one bristle inside, the distal segment with 5 bristles inside, 2 terminal bristles, and 2 bristles outside.
Exopodite with 2 segments, the proximal segment with one bristle inside and a thorn outside, the distal segment with 5 bristles inside, a terminal blade, and 3 thorns outside.

Appendage IX. 3rd Swimming Foot (Plate 5, Fig. 13). The proximal segment of the basipodite with a bristle inside, the distal segment with a thorn outside.
Endopodite with 2 segments, the proximal segment with one bristle inside, the distal segment with 4 bristles inside, 2 terminal bristles, and 2 bristles outside.

Exopodite with 2 segments, the proximal segment with a bristle inside and a thorn outside, the distal segment with 4 bristles inside, a terminal blade, and 3 thorns outside.

Appendage X. 4TH SWIMMING FOOT (Plate 5, Fig. 14). The proximal segment of the basipodite with an inside bristle, the distal segment with a thorn outside.

Endopodite with 2 segments, the proximal segment with one bristle inside, the distal segment with 3 bristles inside, 2 terminal bristles, and 2 bristles outside.

Exopodite with 2 segments, the proximal segment with an outside thorn, the distal segment with 4 bristles inside, a terminal blade, and 3 thorns outside.

Appendage XI. 5TH SWIMMING FOOT (Plate 5, Fig. 15).

Endopodite unsegmented, with 6 bristles.

Exopodite unsegmented, with 3 bristles inside, a terminal blade, and 3 thorns outside.

STAGE V (Plate 4, Figs. 5 and 9). Body much longer, the full number of segments in the thorax and urosome. Antennules, antennæ, mandibles, maxillules, maxillæ, and swimming feet I to IV like the adult. The maxilliped has not yet the full number of bristles (Plate 5, Fig. 16). 1st segment with 5 bristles, 2 with 3, 4 with 2 inside and one outside, terminal segment with 4 bristles. The swimming feet (Plate 5, Figs. 17–21) are all like the adult with the exception of the last, which, although having the full number of bristles, has only 2 segments to the endopodite and exopodite.

Stage VI is the fully developed copepod.

LITERATURE.

1902. GRAN, H. H.—Das Plankton des Norwegischen Nordmeeres. Report on Norwegian Fishery and Marine Investigations. Vol. II, 1902, No. 5.

1881. GROBBEN, C.—Die Entwicklungsgeschichte von Cetochilus septentrionalis Goodsir. Arbeiten aus dem Zoologischen Institute der Universität Wien, etc. Vol. III, Part 3.

1906. OBERG, M.—Die Metamorphose der Plankton-Copepoden der Kieler Bucht. Wissenschaftliche Meeresuntersuchungen herausgegeben von der Kommission zur Wissenschaftlichen Untersuchung der deutschen meer in Kiel, etc. N.S. Vol. IX. Abt. Kiel.

1903. SARS, G. O.—An Account of the Crustacea of Norway. Vol. IV. Copepoda Calanoida.

The work on the Copepoda of the Danish Ingolf Expedition, Vol. III, Part 4, 1915, by Carl With, came to hand after the present paper was in print.

EXPLANATION OF FIGURES.

Plate 1.—1. Nauplius Stage I. × 80.
2. ,, ,, II. ,,
3. ,, ,, III. ,,
4. ,, ,, IV. ,,
5. ,, ,, V. ,,
6. Copepodid ,, I. ,,

Plate 2.—1. 1st Appendage (Antennule) of Nauplius I.
2. ,, ,, ,, ,, II.
3. ,, ,, ,, ,, III.
4. ,, ,, ,, ,, IV.
5. ,, ,, ,, ,, V.
6. 2nd ,, (Antenna) ,, I.
7. ,, ,, ,, ,, II.
8. ,, ,, ,, ,, III.
9. ,, ,, ,, ,, IV.
10 ,, ,, ,, ,, V.
11. 3rd ,, (Mandible) ,, I.
12. ,, ,, ,, ,, II.
× 175.

Plate 3.—1. 3rd Appendage (Mandible) of Nauplius III.
2. ,, ,, ,, ,, IV.
3. ,, ,, ,, ,, V.
4. 4th ,, (Maxillule) ,, IV.
5. ,, ,, ,, ,, V.
6. 2nd ,, (Antenna) of Copepodid Stage I.
7. 3rd ,, (Mandible) ,, ,,
8. 4th ,, (Maxillule) ,, ,,
9. 5th ,, (Maxilla) ,, ,,
10. 6th ,, (Maxilliped) ,, ,,
× 175.

CX	Coxopodite.
B	Basipodite.
EP	Epipodite.
END	Endopodite.
EX	Exopodite.
G	Gnathobase.

Plate 4.—1–5. Dorsal view of Copepodid Stages I–V.
× 18.

6–9. Lateral view of Copepodid Stages II–V.
× 18.

Plate 5.—Distal portion of Maxilliped and Swimming Feet of Copepodid Stages II–V.
× 26·6.

Experiments on the Mendelian Inheritance of Eye-colour in the Amphipod *Gammarus chevreuxi.*

By

E. W. Sexton, F.L.S.,

Marine Biological Laboratory, Plymouth.

AND

M. B. Wing.

With Plate I.

CONTENTS.

	PAGE
General conditions—habits, water, air, food, light	19
Explanation of terms employed in paper	21
The pigmentation of the eye—black, red, "all-white," "part-white," and "no-white"	21
The first appearance of the Red eyes	22
Results of examinations of dredgings	24
Experimental work—question of sex-limitation	26
I. Recessives to the sixth generation	26
II. Dominants—Pure Blacks	28
Proportions of P. and H.	29
Hybrids—Parent generation	30
F_1 generation	31
F_2 generation	31
K, M, and N families	31
Proportions of Black and Red	32
Proportions of Pure and Hybrid	34
Table of results	35
Preponderance of colour	39
Results of Black crosses	41
Sex of survivors	42
Records of Abnormal Eyes	43
General notes—breeding different generations, etc.	46
Summary	48

The Amphipod which was used in the following experiments was described in 1913 (*Journ. M.B.A.*, Vol. IX, pp. 542–545) under the name of *Gammarus chevreuxi*, and its life history was then worked out (see Sexton and Matthews, *l.c.*, pp. 546–556).

The usual colour of the eye in this species, as in the other species of the genus *Gammarus*, is black, but several females and young with red eyes were observed while the above work was in progress. Beyond recording the fact, however (*l.c.*, pp. 543 and 552), no special attention was given to the matter.

The descendants of two original pairs taken in June, 1912, were kept under observation for moults, etc., in the Laboratory until August, 1913, when the present writers undertook to investigate the variation in eye-colour, with a view to determining first if it were a sex-limited character, and secondly, if it conformed to the Mendelian law of inheritance.

In the course of these investigations we have received constant assistance and advice from the Director, Dr. E. J. Allen, F.R.S., at whose suggestion they were first undertaken, and we wish here to acknowledge our great indebtedness to him.

GENERAL CONDITIONS.

Before entering into the detailed results of the experiments it will be necessary to give a brief description of the habits of the species as well as of the conditions under which the animals were kept in the Laboratory.

Gammarus chevreuxi is an ideal species for experimental work. It is very hardy, quickly reaches maturity, and breeds all the year round. The young are extruded from the marsupial pouch and another batch of eggs laid generally within 24 hours of the time of hatching. During the summer season a brood takes from 12 to 14 days to hatch, and the period of sexual activity is reached at the age of 36 days ; in winter in natural conditions a brood takes 30 days to hatch, and does not become sexually mature for at least 3 months, low temperature, as would be expected, retarding development. In the Laboratory, however, which is heated in the winter, there is practically no difference in the seasons, and it therefore becomes possible to obtain several generations in the year.

It may be well to state here that in this species of *Gammarus* the female never lays eggs unless a male is present, and also that it is absolutely impossible for a male to fertilise two broods of eggs with one deposition of sperm. The male generally takes the female a few days before the eggs hatch, and carries it until the young are extruded from the pouch. The female then moults, assisted by the male, as described in the paper referred to above (*l.c.*, p. 550). The aperture of the oviduct is opened by the removal of the old cuticle, and the male deposits the sperm in the pouch around it, but unless the eggs are laid within a few hours they cannot be laid at all. The cuticle hardens rapidly, and a plug of the glutinous lubricatory matter which accompanies moulting and oviposition closes the aperture and hardens to the consistency of the cuticle, effectually blocking the oviduct, until another moult takes place and the plug is sloughed with the old cuticle.

Another point must be mentioned in regard to the suitability of this species for laboratory work, and that is the ease with which it adapts itself to artificial conditions. This is probably due to the fact that it comes from brackish water ditches where it is habituated to great variations of temperature, salinity, pressure due to depth of water, etc. The density, for example, varies to an extraordinary degree according to the season, tides, excessive rainfall or drought, ranging from 1 to 1·028.

In the experimental work, it has been necessary to keep the water as nearly as possible at the same salinity, as any sudden change of conditions always affects the animals' growth and breeding. A mixture of one part of sea-water to six parts of fresh water gives the same density (1·004) as that found in the ditches when the animals were taken, and such water we have generally used.

The best results have been obtained by keeping the animals in finger-bowls, generally one pair in a bowl. Each bowl contained about 200 c.cs. of water, and was covered with a glass plate to check evaporation and exclude dust. No aerating apparatus was used, the animals obtaining sufficient air for their needs from the surface of the water exposed in the bowls. In the same amount of water but with a smaller surface exposed to the air they did not flourish at all, as was found later when using jam jars and honey jars for the broods; only a very small proportion of the young reached maturity.

For food dry leaves of all kinds were used, after they had been allowed to rot in water. It was found that the animals preferred the soft tissues of the leaves of elm, hazel, and sycamore, rather than the harder leaves of oak, beech, etc. A fine delicate Ulva from the ditches they ate freely, but when the supply failed and the harder marine variety (*Ulva latissima*) was given, they did not eat it until it macerated. They flourish better and are much healthier with some of the mud from the ditches in the bowls, but in all these experiments we were obliged to keep the water clear, in order to watch the animals without disturbing them unnecessarily. The young are so minute—about 1 mm. in length when hatched—that they completely escape observation in the mud, clinging as they do to any particles of dirt or weed.

The bowls were kept in ordinary diffused light, strong sunlight being avoided.

A word of explanation is necessary as to the terms employed in this paper. The Black eye-colour is dominant to the Red, and therefore Red is referred to as Recessive (R.). Black divides into Pure (P.) and Impure, but instead of the term "impure" the word Hybrid (H.) is used.

THE PIGMENTATION OF THE EYE.

The structure of the eye of *Gammarus* has been well described and figured by Parker ("The Compound Eyes in Crustaceans," *Bull. Mus. Comp. Zool.*, Harvard, Vol. XXI, Plate I), the species investigated by him being the *Gammarus ornatus* of Milne-Edwards (=*Gammarus locusta*, Linn., Stebbing, *Das Tierreich*, V. 21, p. 476).

Sections of the eye of *Gammarus chevreuxi* show precisely the same internal structure. The eye in this species is reniform in the adult, oval in the young animal, much raised and rounded. The superficial aspect presents a reticulation of opaque white pigment, with the ommatidia appearing as coloured spots, black or red, in the spaces of the network.

The black pigment of the retinular cells of the ommatidia of the *Black* eye appears to be produced by a combination of black and red, even in the so-called "Pure Black" animals (Fig. 1), with a larger admixture of the red in the "Hybrid Blacks" (Figs. 2 and 4).

The pigment of the *Red* eye is pure red, with no alloy of the black (Figs. 3 and 5).

Sometimes the retinular cells are unpigmented and the white reticulation shows up in a very striking way, giving the effect of chalk-white eyes—the "*All-white*" eye referred to in the paper (Figs. 8, 9, and 10).

Occasionally again, some of the ommatidia are pigmented and some not; this variation is called the "*Part-white*" eye (Fig. 7).

The white opaque pigment is subject to great variation, sometimes showing as faint thread-like lines, sometimes broken up and irregular, sometimes present in excess, obscuring the ommatidia, and sometimes it is entirely lacking, the "*No-white*" eye (Fig. 6). Animals are often found with one or both eyes affected. The defect can be transmitted by normal-eyed animals to both black and red eyed offspring.

THE FIRST APPEARANCE OF THE RED EYES.

Two pairs of *Gammarus chevreuxi* were taken in June, 1912, those referred to in the previous paper as Pair I and Pair II. All four animals were black-eyed.

All the broods from Pair II were black-eyed. This stock (which is referred to as the " Pure Black " stock) has been kept under observation from June, 1912, till now, December, 1915, fresh black-eyed material from the ditches being added from time to time. Not a single red-eyed animal has appeared in it. The strain was tested by mating also, to make absolutely certain of its purity before using it in the experiments.

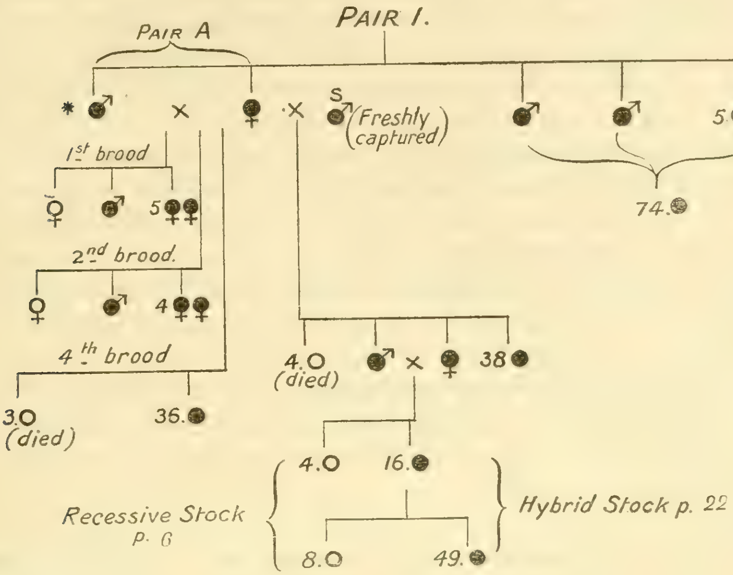
The first brood from Pair I were all black-eyed: 9 young ones coming to maturity, 3 males and 6 females. The first pair to mate (Pair A) were evidently the strongest, and had the largest broods, although owing to unfavourable conditions only a few in each brood survived. The first brood from this Pair A numbered 18 ; the young were counted on hatching, but not examined for eye-colour ; of these 1 male and 6 females came to maturity, one of the females with red eyes. The second brood was 28 in number, 1 male and 5 females surviving, and again one female had red eyes. For the third mating of the female A a different male was used (male S), one which was freshly captured. The ensuing brood was extruded on October 26, 1912, 44 in number, and as these were being separated into finger-bowls for observation of moults 4 red-eyed ones were found. Male A was then put back with the female A, for the fourth mating ; the brood numbered 39, 3 with red eyes.

It will be seen that this female, mated with two different black-eyed males, produced some red-eyed young in each brood. No red eyes were observed in any of the other offspring of Pair I nor in their progeny.

The four red-eyed young of the third brood died before reaching maturity, and the remainder of the brood were kept separate, each in a finger-bowl, until they were 66 days old. On December 31 they were put together in a bell-jar, and some mated at once. The first female to mate of this brood was separated from the others, and from her and her offspring all the red-eyed stock has descended.

By August 7, 1913, this female and its mate were dead, and only 20 young were found in the jar, 16 black-eyed and 4 red-eyed. The four were removed, and the black-eyed left together for three months longer ; when again examined on November 5 the numbers were 65 black-eyed and 8 red, and with these work was commenced.

The following scheme shows the origin of this red-eyed stock, clear circles indicating the red-eyed, black circles the black-eyed animals :—



* The male of Pair A mated with two of the other females of the same brood ; the resulting young numbered 27, all black-eyed.

It cannot, of course, be stated as an absolute fact that red-eyed specimens never occur in the ditches in natural conditions, but so far not a single one has been found, although thousands of specimens brought in at different seasons of the year have been examined. The red strain has only shown itself in the one female, female A and her progeny. It seemed possible at first that the red-eyed strain could be accounted for on Mendelian lines. If the original Pair I had been a Pure Black mated with a Hybrid Black all the offspring would have been black-eyed, half the number Pure Blacks and half Hybrid Blacks ; and if in their matings a Hybrid should mate with a Hybrid the red-eye strain should have appeared. But, as far as can be seen, only the female A had the red strain ; both her mates, male A and male S, when mated with other females (some from the same brood as female A and some from other stocks) had only black-eyed offspring, and, moreover, in none of the other members of the brood nor in their offspring has the red strain appeared. It might have been that male A was a Hybrid Black and that female A was the only Hybrid Black female in the brood, but it seems pushing coincidence too far to suggest that male S captured some months later and taken at random from a large dredging should be a Hybrid and the only Hybrid in it. None of the others captured then or at any other time have shown the red strain.

One series of 5000 was counted, for example, and all were black-eyed. Considering, however, that this way of examining the eyes was not a sufficiently accurate test, it was decided to take two dredgings, a winter one and a summer one, of as many animals as could be found at the time in all the ditches as the result of a day's collecting. These were to be counted, each one examined for eye-colour, each ovigerous female to be separated until its brood hatched, and each brood to be counted and examined. A number of adults were to be taken and mated with red-eyed mates, and their young examined. And finally, the most important test of all, a number of mated pairs were to be kept and bred to the F_2 generation, to see if captivity and inbreeding would repeat the result obtained with the Pair I of June, 1912.

The first dredging for this purpose was made on February 11, 1915. 373 animals, all black-eyed, were found, 198 of which were adult females; the greater part of the remaining 175 specimens were males, the rest were immature. Of the females, 112 had eggs, the others, 86 in number, were paired.

The 112 ovigerous females were separated, and their young counted on extrusion. The broods in many cases were small, many of the animals having apparently not long reached maturity; e.g. the first broods to hatch were in number as follows: 11, 3, 15, 4, 9, 11. In all, the number of young extruded was 641, all of them black-eyed.

Forty-six adults were mated with Red mates; all produced black-eyed offspring, proving beyond doubt that they were Pure Black and not Hybrid. The number of broods counted was 62, the number of young 853.

Twelve of the 86 black-eyed pairs brought in from the ditches were taken to breed to the second generation of offspring. Of these Pairs II to XII * were kept for two or three broods each, and then returned to the rest of the dredging. The total number of young in the first generation of offspring from these broods was 473, all black-eyed.

For the second generation, one brood from each of the Pairs II to XII was taken, the first to mature in each case. This was done because the red eyes appeared in the first brood of the first F_1 pair of the original stock (p. 22).

When these broods reached maturity some of the mated pairs were separated and the others allowed to mate in the brood-bowl, the young in all cases being removed as soon as possible and examined for eye-colour.

---

* Pair I produced no young, the female throwing off the eggs; the male was then paired with three other females, two Black from the dredging, and one Red from the old stock; all laid eggs, but no young were hatched, and the male died.

215 young were counted, all black-eyed ; some of these have commenced breeding.

This generation is very interesting from the fact that in it, as in the same generation of the original stock, a deviation from the normal occurred. In the case of the original stock the black pigment was absent, and the result was a red eye with the superficial network of opaque white pigment unaltered. In this second case the black pigment was present in every instance, but in the broods of Pair V the white pigment was affected in greater or less degree. The female of this pair had less white than is usual in the eye—the reticulation was perfect, but the lines of white were very thin and thread-like. The eyes of the young in the first generation were the same, but in the young from the first pair of these that mated there was considerable variation. One brood of 13 contained 2 young with "no-white" eyes on both sides (Fig. 6), 5 others with the white reticulation very faintly marked, and 6 with eyes like the male parent and female grandparent. This brood is being kept separate to see if the defect follows the Mendelian lines of inheritance of characters.

No individuals of the third generation from these pairs have been hatched yet (Nov. 19, 1915), but 60 which have been examined from the General Stock bowl all have normal black eyes.

The summer dredging was taken on July 6, 1915. 372 living animals were examined, all black-eyed. A good many more were brought in, but did not survive overnight, owing to the heat and overcrowding of the pots and consequent fouling of the water.

Twenty-two adults were mated with Red mates ; 31 broods were counted, containing 348 young, all black-eyed.

Thirteen black-eyed pairs of those paired in the ditches were separated from the others, and placed in finger-bowls to breed to the second generation. By November 19, 1915, there were 127 of the first generation and one brood, 5 in number, of the second generation, all with black eyes and all normal except the offspring of one pair. In this bowl, four of the first generation were left, two females with normal eyes, and two from a younger brood, one with normal eyes, and the other with a white patch on each eye at the upper end caused by three or four of the ommatidia being unpigmented, the "part-white" eye (cf. Fig. 7 for an example of this in the Recessives). This is the first occurrence recorded in the course of the work of a variation appearing in the *first* generation from animals brought in from the ditches.*

---

* Only one specimen has been recorded from freshly captured animals, a male, with the left eye affected.

EXPERIMENTAL WORK.

The first question to be decided was whether the red eye-colour was a sex-limited character or not—the only adult specimens previously observed having been females.

In order to settle this point the 8 red-eyed young found on November 5 (p. 22) were placed in a bowl by themselves to come to maturity. It is impossible to distinguish males from females until the animals reach sexual maturity, which occurs when they are about half-grown, the males being then easily distinguishable by the fine coiled hairs of the lower antennæ, and by the larger gnathopods. The 4 red-eyed young of August 7 were kept in the Laboratory, only two coming to maturity, both female. The 8 red-eyed young of November 5 were kept in another room, not heated, with a temperature ranging from 4°–10° C., and were in consequence much slower in maturing; but in three months' time both males and females were seen—thus settling the question of the red eye-colour being a sex-limited character. In February three pairs mated. These were kept separate, each pair in a finger-bowl to itself, and the others, which were females, with the two August 7 females, were paired with males from the " Pure Black " stock. Males and females paired were also taken from this stock, and thus we had Recessive mated with Recessive (R. × R.), Pure Black mated with Recessive (P. × R.), and Pure Black mated with Pure Black (P. × P.). We started daily observations and records on this generation, calling it the Parent Generation, and counting from it the F_1, F_2, etc.

Our aim now was to discover if the Mendelian laws of inheritance of characters were applicable to the results of these crosses, and the experiments to this end will be given in detail under the different divisions —I Recessives and II Dominants.

I. THE RECESSIVES.

We commenced work in February, 1914, with the three pairs just referred to, adding in May seven pairs taken from the 42 red-eyed animals hatched since November 5, 1913, in the Hybrid Stock (see p. 22). Each pair and its offspring have been kept separate, the broods on hatching removed from the parents' finger-bowl and examined for eye-colour, each brood being numbered and set aside to come to maturity. In every case in which both parents were red-eyed all the offspring have been red-eyed.

The red-eyed animals appear to be more delicate than the black-eyed, shorter-lived, and less fertile. They are quite as large and as active, and in many cases observed, reached maturity *before* the black-eyed in the same brood. Yet, if left to breed together with no admixture of the black-eyed strain, they gradually diminish in numbers, throwing off the eggs sometimes soon after deposition, or dying after having had only one or two broods. Seven of the ten stocks have failed in this way.

The results of the Experiments with the *Parent Generation* are given below in detail. and are typical of all the experiments with inbreeding Recessives. They are as follows :—

Exp. 1. Two broods, 10 and 12 respectively ; female died.
,, 2. Mated, but no eggs laid.
,, 3. One brood ; only 1 young hatched.
,, 4. One brood of 20 young.
,, 5. First brood, only 1 young hatched ; second brood, 3 young. Thinking the small numbers might be due to some defect or unhealthiness in this male, it was taken away and another added. Third brood, only 1 young hatched. Male again changed. Fourth brood, 14 young; fifth brood, eggs thrown off before hatching. Male again changed. Sixth brood, 17 young.
,, 6. One brood, 19 young. A second brood was laid, but the female died before the eggs were hatched.
,, 7. Mated, eggs laid, but thrown off before hatching, probably unfertilised.
,, 8. Mated, eggs thrown off as in Exp. 7.
,, 9. One brood, 10 young. A second brood was laid, but the eggs were thrown off before hatching.
,, 10. Mated, eggs thrown off as in Exps. 7 and 8.
,, 11. Mated, eggs thrown off as in Exps. 7 and 8.

The total results for six months for the Parent Generation were : One pair mated, no eggs laid ; seven broods not hatched ; eleven broods hatched, the young numbering in all 108 ; average per brood 9·8. Only about half of these survived to maturity.

In the next generation, the F_1, a rather different system was followed. In some cases records of separate pairs were kept, in other cases the whole brood was left together in a finger-bowl, each female removed after oviposition, kept separate until the eggs were hatched, and then returned to the brood-bowl to mate again.

The total results in the twelve months from July, 1914, to July, 1915, for the breeding of the F_1 generation are : 2 pairs mated with no results ; 80 broods from the other pairs, 20 of these not hatched, 60 hatched, numbering 422 young (these are the F_2 generation), average 7 per brood, a smaller average than in the preceding generation.

In the *F_2 generation* the same system was followed as in the F_1, the ovigerous females being removed from the brood-bowl till they had extruded their young, and then returned to it. But in one or two cases where only males or only females were left of a brood, mates from a different brood, but of the same family and the same generation, were added. These records were kept separately. The females of the first category laid 26 broods between September, 1914, and October, 1915, and hatched 207 young. One pair mated twice with no results, and two other pairs also mated with no results. In the second case, where male and female came from different broods, only two broods, of 7 and 8 young respectively, were hatched, the male in each case dying soon after, but these broods appear stronger than the others.

Several of this F_2 generation are still breeding (Nov. 3, 1915), but the numbers already obtained are sufficient for proof and record.

Of the *F_3 generation* 105 have survived (Nov. 19, 1915), many of them not yet mature. In several broods all the individuals have very pale eyes, with hardly any of the red pigment showing. The results for this generation are unsatisfactory, only a few young being hatched. Ten pairs have mated so far, as follows :—

From the first category (individuals of the same brood paired in their brood-bowl) 2 pairs mated, no eggs laid ; 1 pair mated, eggs thrown off ; 3 pairs with 18 young in 4 broods.

From the second category, which appears to yield a stronger stock (the two F_3 broods of the two F_2 pairs in which male and female came from different parents), 4 survive of the first brood of 7, not yet mature ; the second brood of 8 matured, and 6 matings have taken place : 4 young (all dead now) ; eggs thrown off ; no eggs ; 9 young (all dead) ; 7 young (1 left) ; and 5 young (3 left, mature females).

The total number for the *F_4 generation* thus far is only 31. Some individuals of one brood, the 9 young referred to above, came to maturity, and 2 broods of *F_5* were hatched, numbering 12 young. Of these 9 survived, and are now nearly ready to breed.

II. THE DOMINANTS.

The Dominants are divided into *Pure Black* and *Hybrid Black*, which will be dealt with under separate divisions.

According to the Mendelian laws of inheritance of characters, the matings of the Dominants with other Dominants and with Recessives should show the following results :—

(*a*) P. × P. : mating of Pure Black with Pure Black should give all black-eyed offspring, Pure Black, which should breed true through all succeeding generations.

(*b*) P. × H. : matings of Pure Black with Hybrid Black should give all black-eyed offspring, half Pure Black and half Hybrid Black.

(*c*) P. × R. : mating of Pure Black with Recessives should give all black-eyed offspring, Hybrid Black, which when bred together should show the red-eyed strain in the next generation.

(*d*) H. × H. : matings of Hybrid Black with Hybrid Black should give three black-eyed offspring to one red-eyed, i.e. in the proportion of one Pure Black and two Hybrid Black to one Recessive.

(*e*) H. × R. : matings of Hybrid Black with Recessive should give offspring half of which would be Hybrid Black and half Recessive.

The Pure Blacks.

Only a short note is necessary under this heading.

The Pure Black stock (p. 22) has been kept and interbred for over three years in a large jar. Observations have been made on it at different seasons of the year, all the animals being taken out and examined for eye-colour. Different pairs also have been kept separate from time to time and their progeny recorded to the third and fourth generations, but in all the cases not a single red-eyed one has been found.

With other dredgings brought in at intervals since June, 1912, the same results have been obtained. The last dredgings examined were those described on p. 25.

With regard to the 194 young from the P. × P. matings mentioned on p. 41, the record of the number of their offspring has not been kept, it having been thought sufficient to examine the eye-colour of all the animals in the different bowls from time to time to make sure that no red-eyed one appears.

In the P. × H. matings which have been tried, the young were all black-eyed. The difficulty with these has been in bringing a sufficient number of any one brood to maturity in order to test them for P. and H. characters. Only one case succeeded well enough to be recorded, the Brood 1 of Experiment 118 referred to on p. 41. Twenty-two young were hatched, and twenty-one reached maturity—seven males, thirteen females, and one abnormal one. Each of these was mated with a red-eyed mate except in the two instances noted, when a proved Hybrid mate was used, with the following results :—

P.♀	13	young.	Black.
H.♂	120	,,	67 Black and 53 Red.
? ♀	4 mates, 2 P. and 2 R.		5 broods laid, none hatched.
P.♂	64	young.	Black.
H.♀	14	,,	8 Black and 6 Red.
P.♀	6	,,	Black.
P.♀	71	,,	Black.
P.♀	165	,,	Black. The eye of this female is figured. See Fig. 1.
P.♀	56	,,	Black.
H.♀	8	,,	5 Black and 3 Red.
? ♀	1	,,	Black. Female eaten.
H.♀	15	,,	11 Black and 4 Red.
H.♀	4	,,	3 Black and 1 Red. This female was tested with a Hybrid Black mate.
H.♂	14	,,	10 Black and 4 Red. Also with a Hybrid Black mate.
? ♀			Eaten by mate.
H.♂	57	,,	31 Black and 26 Red.
H.♀	20	,,	12 Black and 8 Red.
P.♂	37	,,	Black.
H.♂	24	,,	12 Black and 12 Red.
P.♂	8	,,	Black.
? ?			This is the Abnormal one mentioned above.

In the third cross (*c*) P. × R., the matings have always produced black-eyed offspring, all Hybrid Black. The figures obtained in the F_2 generation may be quoted here—1563 young (see p. 39), as well as those of the Parent generation given in the next paragraph.

THE HYBRIDS.

Parent generation.

In the *Parent generation* 33 experiments were made, starting in November, 1913, Pure Black males being mated with Recessive females, and Recessive males with Pure Black females, 16 experiments with the first cross, and 17 with the second. There were 18 broods hatched from the first cross P.♂ × R.♀, numbering in all 323 young; and 21 broods from the second cross R.♂ × P.♀ with 313 young. In all these experiments without exception, the young had black eyes. In the first cross some paired without results, the others had from one to six broods each, the largest number in a single brood being 38. In the second cross, all but one of the broods were hatched, the largest number being 49.

F_1 generation.

All the young of this generation were black-eyed, as was to be expected, in accordance with the Mendelian law that the offspring of Dominant mated with Recessive resemble the dominant parent in character. The further development of the law, that though the offspring are dominant in appearance, yet in constitution they are hybrid, could not be determined until the next generation, the F_2, appeared, the eye-colour alone not being a sufficiently accurate guide in distinguishing Pure Blacks from Hybrid Blacks.

In order to make sure of each individual F_1 and to keep its history clear, all the F_1 broods were kept in separate bowls till mature, and then as each pair mated it was removed and records kept of all the matings, the young being counted and examined for eye-colour immediately after extrusion from the pouch. All the F_1 that reached maturity were tested and all proved Hybrid Blacks.

The results for the eye-colour in the F_2 generation are given below.

F_2 generation.

The first idea was to take the F_2 broods in order as they hatched to the number of 1000 young, and to find if the proportions held good—three black to one red. Seventy-four broods were taken in this way, the young numbering 586, 437 of which were black-eyed and 149 red-eyed, the reds therefore being very slightly in excess of the theoretical figure. These broods appeared during the summer months, when the animals mature more rapidly and have a much quicker succession of broods than in the lower temperature. As the numbers in the broods were decreasing, the adults dying off, and the whole of the stock looking unhealthy, it was thought well to strengthen it before continuing the experiment. A change of food was given, and plenty of mud from the ditches.

It was then decided to pick out the three largest and strongest of the F_1 broods, and to count all the F_2 progeny produced by them. K, M, and N broods, which had matured under the healthier conditions, were chosen—K brood consisted of five males and nineteen females, M of nine males and six females, and N of fifteen males and seven females.

The first 72 broods from these three families (from Oct. 22, 1914, to March 2, 1915) contained 1004 young, 753 black-eyed and 251 red-eyed, in the exact proportion, as will be seen, of 3 to 1. K family was represented by 43 broods, total number of young hatched 655, of which 487 were Black and 168 Red; M family by 19 broods, 271 young, 204

Black and 67 Red ; and N family by 10 broods, 78 young, 62 Black and 16 Red.

By this time the animals were beginning to die out. N family was finished by June 16, 1915 ; M family on that date had only 1 male and 4 females left (this male died on July 22) ; while K family still had 3 males and 16 females.

The next 65 broods (to May 24, 1915) brought the number of young extruded to 2000=1505 Black and 495 Red : K family with 1228, 924 Black and 304 Red ; M family with 582, 438 Black and 144 Red ; and N family with 190, 143 Black and 47 Red.

The number 3001 was reached on July 24, 1915, total number of Black 2270, and of Red 731 ; K family with 1540 Black and 490 Red ; M family with 552 Black and 181 Red ; and N family with 178 Black and 60 Red.

The figures therefore for the second and third thousand give to the Blacks a slight excess over the theoretical figure. In the first thousand (1004) the proportions, three Black to one Red, were exact ; in the 2000 they were very nearly right ; but in the 3000 the Black rather predominated, the fact that the Black is the hardier strain probably accounting for this.

This same slight but steady increase can be seen on a small scale in the detailed Brood-records of the Hybrid crosses H. × R. In the first broods of each pair the proportions are nearly always exact, half Black and half Red, but the total results for all the broods show a preponderance of Black (see lists, p. 35) ; compare also for an example of a single brood Exp. 85, p. 38.

In Exp. 85 Brood	1 numbered	24 =	12 Black,	12 Red.
,,	2 ,,	25 =	13 ,,	12 ,,
,,	3 ,,	23 =	12 ,,	11 ,,
,,	4 ,,	28 =	14 ,,	14 ,,
,,	5 ,,	20 =	9 ,,	11 ,,
,,	6 ,,	32 =	20 ,,	12 ,,
,,	7 ,,	17 =	8 ,,	9 ,,
,,	8 ,,	21 =	13 ,,	8 ,,
,,	9 ,,	14 =	8 ,,	6 ,,
,,	10 ,,	26 =	15 ,,	11 ,,
,,	11 ,,	34 =	15 ,,	19 ,,
,,	12 ,,	42 =	25 ,,	17 ,,
,,	13 ,,	26 =	12 ,,	14 ,,
Total .	13 broods.	332 young.	176 Black.	156 Red.

The records of the individual families are very interesting. In K family, in which females preponderate, breeding commenced October 25, 1914, the first thousand was reached on April 20, 1915: 63 broods hatched out numbering in all 1007 young, of which 756 were Black and 251 were Red, exact proportions. In the second thousand there were 59 broods hatched containing 1003 young, 767 Black as against 236 Red, the Black therefore in excess. 23 more broods were laid with 431 young, 336 Black and 95 Red. As will be seen, the proportion of Black is again higher. The last male died on September 21, 1915, on which date the records were perforce brought to a conclusion.

These figures prove conclusively that in the F_2 generation the proportions are 3 black-eyed to 1 red-eyed. The next step was the testing the black-eyed F_2 to get the proportion of Pure Black to Hybrid Black, but the results of this work are not exact and naturally cannot be. It is easy enough to separate the colours, black from red, immediately on hatching, but impossible to determine the question of the constitution of the black-eyed until they breed. Owing to various causes a high rate of mortality has to be allowed for, and the results therefore can only be given on the *survivors*.

The animals undergo many ecdyses, the young every few days, the adults at longer intervals, the males again at much longer intervals than the females. The moulting period is always critical even to the strong ones. It is absolutely fatal to the weakly ones in a brood, the others attacking them in their feeble condition and devouring them. With the adults the mortality is higher among the females. The reason is that the male carrying the female for some days prior to the extrusion of a brood, and assisting it through the moult which immediately precedes the deposition of a fresh brood, very frequently ends by eating it directly after. A great many females have been lost in this way in the course of the work.

But the principal cause of the high death rate is the development of injurious bacteria in the bowls. At first it was thought that the bacteria had been introduced with the rotting leaves given as food, and many methods of sterilising the leaves were tried. After a while it was noticed that all the broods set out on a certain date had perished, and on comparing this result with a similar one in Mr. Crawshay's experiments, he discovered that the same sea-water had been used in all, and that this water was infected, although taken as far out as the Eddystone for the sake of avoiding shore contamination.

Several kinds of bacteria have been observed, some fatal within a day or two, some after several weeks, and others which, except for retarding development, do not injure the animal. One of this last-mentioned kind turns the water a milky colour, and forms dense slimy masses all round the bowl, and over the food, and even clings to the amphipods themselves. With a lens it is easy to see long streamers of this slime trailing behind the little creatures as they swim.

Proportions of Pure Black to Hybrid Black in the F_2 generation.

The experiments to find the proportions of Pure Black and Hybrid Black were made with the surviving F_2 progeny of the first F_1 brood, Brood A, that came to maturity. The following table shows the parentage with the number of young hatched, 210 in all, 153 black-eyed and 57 red-eyed.

P. ♂ × R. ♀ *Parent generation.*
(From Pure Black stock.) | (One of the 8 Reds, p. 26.)
First Brood—Brood A = 22 young. Hybrid. F_1 *generation.*
extruded 16.3.1914.

A.F_1 pair.	B.F_1 pair.	C.F_1 pair.	D.F_1 pair.	E.F_1 pair.	F.F_1 pair.	G.F_1.
4 broods.	4 broods.	1 brood.	2 broods.	3 broods.	2 broods.	1 brood.
55 young.	48 young.	7 young.	20 young.	43 young.	27 young.	10 young.
						F_2 *generation.*
Hatched :—						
38 Black.	37 Black.	6 Black.	15 Black.	30 Black.	21 Black.	6 Black.
17 Red.	11 Red.	1 Red.	5 Red.	13 Red.	6 Red.	4 Red.
Survived :—						
23 Black.	15 Black.	4 Black.	13 Black.	18 Black.	15 Black.	5 Black.
10 Red.	7 Red.	0 Red.	3 Red.	7 Red.	4 Red.	3 Red.

Only 127 reached maturity, 93 black-eyed and 34 red. Of the Black 44 were males and 49 females ; of the Red 20 were males and 14 females.

The testing was done with red-eyed mates, the Blacks being separated into finger-bowls and each given a Red mate. The resulting broods would at once show the P. or H. character, for if the black-eyed animal were a Pure Black the offspring would be all black-eyed ; if a Hybrid Black, half the young would be black-eyed and half red-eyed. Later, when the constitution of each had been determined, the survivors were mated together : P. × P. ; P. × H. ; H. × H. ; and H. × P.

It sometimes happens that the individuals of the first brood of Hybrid × Recessive, if few in number, are all of one eye-colour, not the normal proportions, half red and half black. This occurred six times in the course of these experiments ; in four broods the young were all black-eyed ; in two, all red ; the highest number in any of these broods was four. To avoid error each pair was kept for at least three broods to make quite sure of the constitution ; in some cases the black-eyed were mated with two or three different red-eyed mates.

In all 141 experiments were made with the 93 Black-eyed animals. Thirteen, 7 males and 6 females, died without proof, probably through some inherent weakness; in one or two cases broods of eggs were laid but not hatched, in others the stronger mate ate the weaker one.

Of the 80 that survived, 22 proved Pure Black, 8 males and 14 females, and 58 proved Hybrid Black, 29 males and 29 females. Ten experiments were made with P. males, 24 with P. females, 38 with H. males, and 56 with H. females.

The details of the experiments are as follows :—

TABLE

showing the details of the experiments made with the black-eyed F_2 progeny of one brood of the F_1 generation of Hybrids, from September, 1914, to September, 1915, in order to find the proportion of Pure Black to Hybrid Black. Theoretically it should be 1 P. : 2 H., but, as has been already explained, the results recorded here cannot be considered exact owing to the high mortality amongst the immature.

Experiment Number.	Black. ♂	Black. ♀	Number of Young hatched.	Eye-colour. Black.	Eye-colour. Red.	Number of Broods.	Pure Black or Hybrid Black.
Exp. 1	—	♀	—	—	—	—	No results : ♀ eaten.
,, 2	—	♀	—	—	—	—	No results : ♀ died.
,, 3	—	♀	—	—	—	—	No results : ♀ died.
,, 4*a*	♂	—	—	—	—	—	No results.
,, 4*b*	,,	—	33	All	—	4	P.
,, 5	♂	—	31	16	15	3	H.
,, 6	—	♀	25	15	10	2	H.
,, 8*a*	♂	—	—	—	—	—	No results.
,, 8*b*	,,	—	35	21	14	3	H.
,, 9*a*	—	♀	21	12	9	1	H.
,, 9*b*		,,	—	—	—	—	No results.
,, 10	—	♀	—	—	—	—	No results : ♀ died.
,, 11	♂	-	56	34	22	4	H.
,, 14*a*	♂	—	2	—	2	1	H.
,, 14*b*	,,	—	26	13	13	2	,,
,, 16	♂	—	49	21	28	4	H.
,, 17*a*	♂	—	21	11	10	2	H.
,, 17*b*	,,	—	—	—	—	—	Eggs laid, not hatched.
,, 19	♂	- -	28	All		3	P.
,, 20*a*	♂	—	—	—	—	—	No results.
,, 20*b*	,,	—	9	4	5	1	H.
,, 20*c*	,,	- -	44	22	22	1	,,
,, 21	♂	—	—	—	—	—	No results : ♂ died.
,, 22	—	♀	—	—	—	—	No results : ♀ eaten.

Experiment Number.	Black.		Number of Young hatched.	Eye-colour.		Number of Broods.	Pure Black or Hybrid Black.
	♂	♀		Black.	Red.		
Exp. 23*a*	—	♀	—	—	—	—	No results.
,, 23*b*	—	,,	3	2	1	1	H.
,, 23*c*	—	,,	22	10	12	2	,,
,, 24*a*	—	♀	21	12	9	3	H.
,, 24*b*	—	,,	6	1	5	1	,,
,, 25	—	♀	11	6	5	1	H.
,, 26*a*	—	♀	—	—	—	—	No results.
,, 26*b*	—	,,	70	31	39	4	H.
,, 26*c*	—	,,	—	—	—	—	No results.
,, 27	—	♀	11	7	4	1	H.
,, 28*a*	♂	—	—	—	—	—	No results: ate its mate.
,, 28*b*	,,	—	116	54	62	4	H.
,, 29*a*	—	♀	5	3	2	1	H.
,, 29*b*	—	,,	36	19	17	3	,,
,, 30	—	♀	5	4	1	1	H.
,, 31	—	♀	23	11	12	1	H.
,, 32*a*	—	♀	—	—	—	—	No results.
,, 32*b*	—	,,	50	25	25	2	H.
,, 33*a*	—	♀	—	—	—	—	No results.
,, 33*b*	—	,,	46	All	—	2	P.
,, 34*a*	—	♀	8	All	—	2	P.
,, 34*b*	—	,,	14	,,	—	2	,,
,, 34*c*	—	,,	67	,,	—	5	,,
,, 35*a*	—	♀	13	3	10	1	H.
,, 35*b*	—	,,	10	8	2	1	,,
,, 35*c*	—	,,	55	23	32	2	,,
,, 35*d*	—	,,	34	20	14	2	,,
,, 36	—	♀	58	All	—	4	P.
,, 37*a*	—	♀	35	16	19	2	H.
,, 37*b*	—	,,	76	43	33	2	,,
,, 37*c*	—	,,	5	4	1	1	,,
,, 38*a*	—	♀	71	All	—	4	P.
,, 38*b*	—	,,	13	,,	—		,,
,, 39*b*	—	♀	—	—	—	—	No results.
,, 39*c*	—	,,	—	—	—	—	,,
,, 39*d*	—	,,	35	26	9	3	H.
,, 39*e*	—	,,	—	—	—	—	Eggs laid: ♀ eaten.
,, 40	—	♀	25	All	—	2	P.
,, 41	—	♀	81	42	39	4	H.
,, 42*a*	—	♀	13	All	—	3	P.
,, 42*b*	—	,,	11	,,	—	1	,,

Experiment Number.	Black. ♂	Black. ♀	Number of Young hatched.	Eye-colour. Black.	Eye-colour. Red.	Number of Broods.	Pure Black or Hybrid Black.
Exp. 43	♂	—	—	—	—	—	No results : ♂ killed by mate.
,, 44	—	♀	35	16	19	2	H.
,, 45*a*	—	♀	9	All	—	1	P.
,, 45*b*	—	,,	50	,,	—	2	,,
,, 46	♂	—	10	6	4	2	H.
,, 47*a*	♂	—	29	12	17	3	H.
,, 47*b*	,,	—	—	—	—	—	No results : ♂ died.
,, 48*a*	—	♀	19	All	—	2	P.
,, 48*b*	—	,,	14	,,	—	1	,,
,, 49*a*	—	♀	30	16	14	2	H.
,, 49*b*	—	,,	18	13	5	1	,,
,, 50	—	♀	26	10	16	3	H.
,, 51	—	♀	84	32	52	3	H.
,, 52	♂	—	41	All	—	2	P.
,, 53	—	♀	82	All	—	4	P.
,, 54(1)	♂	—	—	—	—	—	No results.
,, 54(2)	♂	—	—	—	—	—	,,
,, 54(3)	♂	—	—	—	—	—	,,
,, 55	—	♀	108	All	—	5	P.
,, 56	—	♀	—	—	—	—	No results.
,, 57*a*	—	♀	30	14	16	2	H.
,, 57*b*	—	,,	63	36	27	2	,,
,, 57*c*	—	,,	135	65	70	5	,,
,, 59*a*	♂	—	—	—	—	—	No results : ♀ eaten.
,, 59*b*	,,	—	56	All	—	3	P.
,, 60	♂	—	117	63	54	4	H.
,, 61*a*	—	♀	58	34	24	3	H.
,, 61*b*	—	,,	15	11	4	1	,,
,, 62*a*	—	♀	18	6	12	3	H.
,, 62*b*	—	,,	—	—	—	—	No results : eggs thrown off : ♀ died.
,, 63	—	♀	81	All	—	4	P.
,, 64	♂	—	—	—	—	—	No results : ate ♀ : died in moulting.
,, 65	—	♀	63	All	—	4	P.
,, 66*a*	—	♀	12	All	—	1	P.
,, 66*b*	—	,,	145	,,	—	10	,,
,, 66*c*	—	,,	131	,,	—	3	,,
,, 67	♂	—	12	3	9	2	H.
,, 68	♂	—	125	62	63	4	H.
,, 69	—	♀	56	27	29	3	H.

Experiment Number.	Black. ♂	Black. ♀	Number of Young hatched.	Eye-colour. Black.	Eye-colour. Red.	Number of Broods.	Pure Black or Hybrid Black.
Exp. 70*a*	—	♀	—	—	—	—	No results : too young ?
,, 70*b*	—	,,	135	All	—	7	P.
,, 71*a*	—	♀	118	63	55	4	H.
,, 71*b*	—	,,	—	—	—	—	No result : ♀ eaten.
,, 72*a*	—	♀	9	7	2	1	H.
,, 72*b*	—	,,	33	16	17	1	,,
,, 72*c*	—	,,	27	11	16	1	,,
,, 73	♂	—	19	5	14	1	H.
,, 74*a*	—	♀	26	11	15	3	H.
,, 74*b*	—	,,	7	3	4	1	,,
,, 75*a*	—	♀	64	33	31	3	H.
,, 75*b*	—	,,	16	8	8	1	,,
,, 76	♂	—	47	23	24	4	H.
,, 77	♂	—	30	16	14	4	H.
,, 78	♂	—	9	All	—	2	P.
,, 79	♂	—	28	14	14	2	H.
,, 80	♂	—	1	1	—	1	No results of value : [♂ eaten.
,, 81	♂	—	76	All	—	4	P.
,, 82*a*	♂	—	9	6	3	4	H.
,, 82*b*	,,	—	26	11	15	1	,,
,, 85	♂	—	332	176	156	13	H.
,, 87	♂	—	191	95	96	10	H.
,, 89*a*	♂	—	—	—	—	—	No results : ate ♀.
,, 89*b*	,,	—	4	3	1	1	H.
,, 90	♂	—	59	All	—	2	P.
,, 91	♂	—	57	31	26	5	H.
,, 92	♂	—	183	95	88	10	H.
,, 93*a*	—	♀	32	15	17	1	H.
,, 93*b*	—	,,	—	—	—	—	No results : eggs thrown off.
,, 94	♂	—	53	21	32	4	H.
,, 95	—	♀	146	68	78	6	H.
,, 96	♂	—	94	54	40	6	H.
,, 97	♂	—	2	1	1	2	H.
,, 98	♂	—	209	95	114	12	H.
,, 99	♂	—	86	All	—	7	P.
,, 100	♂	—	10	6	4	1	H.
,, 104	♂	—	256	140	116	10	H.
Total 141 Exps.	37 ♂	43 ♀	5494 Young.	3555 Black.	1939 Red.	323 Broods.	P.=8 ♂ and 14 ♀. H.=29 ♂ and 29 ♀.

The total number of young hatched was 5494. Of this number 388 were the black-eyed offspring of P. ♂ × R. ♀ and 1175 of P. ♀ × R. ♂. The number of young from the other cross, H. × R., was 3931—1992 Black-eyed and 1939 Red-eyed—1134 Black and 1098 Red in the mating H. ♂ × R. ♀, and 858 Black and 841 Red in the mating H. ♀ × R. ♂. As will be seen, the proportion is not quite exact, the Blacks being rather in excess. It appears to vary a good deal with the individual, though perhaps the number of offspring from a single pair is not sufficiently large to eliminate mere chance variation. Some animals have a succession of broods fairly evenly divided into Black and Red, while others have a preponderance of one colour or the other, others, again, having first one brood unevenly divided, the next restoring the balance, and so on. Examples of the first will be found in Exps. 87 and 57.

In Exp. 87 (♂ H., with the same mate for all the broods)—

Brood	1	numbered	27	=	14	Black and	13	Red.
,,	2	,,	14	=	5	,,	9	,,
,,	3	,,	14	=	9	,,	5	,,
,,	4	,,	13	=	7	,,	6	,,
,,	5	,,	10	=	5	,,	5	,,
,,	6	,,	13	=	8	,,	5	,,
,,	7	,,	20	=	10	,,	10	,,
,,	8	,,	24	=	11	,,	13	,,
,,	9	,,	32	=	14	,,	18	,,
,,	10	,,	24	=	12	,,	12	,,
			191	=	95	,,	96	,,

Exp. 57 (♀ H., with 3 different mates)—

Brood	1	numbered	8	=	3	Black and	5	Red.
,,	2	,,	22	=	11	,,	11	,,
,,	3	,,	30	=	16	,,	14	,,
,,	4	,,	33	=	20	,,	13	,,
,,	5	,,	21	=	11	,,	10	,,
,,	6	,,	32	=	13	,,	19	,,
,,	7	,,	20	=	8	,,	12	,,
,,	8	,,	38	=	20	,,	18	,,
,,	9	,,	24	=	13	,,	11	,,
			228	=	115	,,	113	,,

For examples of the preponderance of one colour Exps. 60, 61, 71, and 95 will serve; 60 is a ♂ H. and 71 a ♀ H., both had 4 broods each, with 117 and 118 young respectively.

In Exp. 60—

Brood 1 numbered 11 = 7 Black and 4 Red.
,, 2 ,, 28 = 12 ,, 16 ,,
,, 3 ,, 47 = 28 ,, 19 ,,
,, 4 ,, 31 = 16 ,, 15 ,,
117 = 63 ,, 54 ,,

In Exp. 71—

Brood 1 numbered 12 = 6 Black and 6 Red.
,, 2 ,, 24 = 17 ,, 7 ,,
,, 3 ,, 41 = 22 ,, 19 ,,
,, 4 ,, 41 = 18 ,, 23 ,,
118 = 63 ,, 55 ,,

In Exp. 61 the Black are in excess.

Brood 1 numbered 8 = 4 Black and 4 Red.
,, 2 ,, 21 = 12 ,, 9 ,,
,, 3 ,, 29 = 18 ,, 11 ,,
,, 4 ,, 15 = 11 ,, 4 ,,
73 = 45 ,, 28 ,,

In Exp. 95 the Red preponderate (cf. Exp. 51).

Brood 1 numbered 15 = 7 Black and 8 Red.
,, 2 ,, 14 = 5 ,, 9 ,,
,, 3 ,, 24 = 11 ,, 13 ,,
,, 4 ,, 33 = 15 ,, 18 ,,
,, 5 ,, 27 = 15 ,, 12 ,,
,, 6 ,, 33 = 15 ,, 18 ,,
146 = 68 ,, 78 ,,

For illustrations of broods unevenly divided the first broods in Exps. 32 and 72 may be given.

Exp 32. Brood 1 with 23 = 10 Black and 13 Red.
,, 2 ,, 27 = 15 ,, 12 ,,
50 = 25 ,, 25 ,,

Exp. 72. Brood 1 with 9 = 7 Black and 2 Red.
,, 2 ,, 33 = 16 ,, 17 ,,
,, 3 ,, 27 = 11 ,, 16 ,,
69 = 34 ,, 35 ,,

The H. ♀ of Exp. 75 had two broods of 21—in one case 13 Black and 8 Red, in the other 13 Red and 8 Black.

The number of young in a brood varies with the individual, but the numbers in the broods of a single pair do not vary much as a rule: to take an example, Exp. 99 had seven broods as follows: 11, 15, 13, 10, 11, 15, 11.

Exp. 35 is an interesting one, showing the varying proportions of Black and Red with different mates. This female was mated with four males with the following results: with male *a*, one brood of 13 young, 3 Black, 10 Red; with male *b*, one brood of 10, 8 Black, 2 Red; with male *c*, two broods of 28 and 27, with 12 Black and 16 Red, and 11 Black and 16 Red respectively; and with male *d*, two broods of 11 and 23, with 6 Black and 5 Red, and 14 Black and 9 Red respectively.

Many of the F_2 animals had died by the time these experiments were finished, only a few remained to be mated together. Two matings of P.×P. were made, the other P. animals being paired with H. mates.

P.×P.	Exp. 83*a*	5 broods	133 Black-eyed young.	♂ died.
,,	,, 83*b*	2 ,,	61 ,, ,,	♀ died.
P.×H.	,, 84	1 brood	Eggs thrown off.	♂ died.
P.×H.	,, 110*b*	1 ,,	6 Black-eyed young.	♂ eaten.
P.×H.	,, 118	2 broods	48 ,, ,,	♂ died.
P.×H.	,, 119	1 brood	3 ,, ,,	♂ died.
H.×P.	,, 102	1 ,,	43 ,, ,,	♂ died.
H.×P.	,, 105*a*	3 broods	85 ,, ,,	♂ died.
H.F_3×P.F_2	,, 105*b*	4 ,,	113 ,, ,,	♂ eaten.
H.×P.	,, 107	—	—	♀ died.
H.F_3×P.F_2	,, 115	1 brood	5 ,, ,,	♂ died.
H.×P.	,, 117	—	—	♂ died.
Total .	.	In 21 broods	497 Black-eyed young.	

The matings of H.×H. are as follows:—

H.×H.	Exp. 86	2 broods	60 young	= 46 Black	14 Red.	♀ eaten.
H.×H.	,, 103	1 brood	22 ,,	= 16 ,,	6 ,,	
and another brood (♂ unhealthy)			1 ,,	= 1 ,,	—	♂ died.
H.×H.	Exp. 106*a*	1 brood	52 ,,	= 48 ,,	4 ,,	♂ died.
,,	106*b*	—	—	= —	—	♀ died.
H.×H.	,, 109	4 broods	62 ,,	= 43 ,,	19 ,,	♂ died.
H.×H.	,, 110*a*	1 brood	38 ,,	= 30 ,,	8 ,,	♂ died.
H.×H.	,, 112	2 broods	40 ,,	= 29 ,,	11 ,,	Both died.
H.×H.	,, 116	1 brood	11 ,,	= 7 ,,	4 ,,	♂ died.
Total .		In 12 broods	286 young	=220 Black	66 Red.	

The proportions of Black to Red in these H. × H. experiments are about right if Exp. 106*a* is not counted.

The H. male in this experiment had been previously mated with a Red female, and had had one brood of 9 young, 1 Black and 8 Red—a preponderance of Red.

The H. female had also been previously mated with a Red male, and had had 84 young in 3 broods, 32 Black to 52 Red, a preponderance of Red. When mated together the one brood of 52 was the result, 48 Black to 4 Red—a preponderance of Black. (The Red male with which the H. female mated was tried with another H. female which had already had 30 young, 16 Black and 14 Red—with the result, one brood of 18 young hatched, 13 Black and 5 Red.)

A great many of the F_3 animals from these experiments were mated in order to see if the results would repeat those already obtained in the P. F_1 and F_2 generations. They were examined regularly, but only a few records were kept, the fact that in all cases they bred true being considered sufficient evidence of accordance with the Mendelian law.

SEX.

All the broods were kept in separate bowls to come to maturity, in the hope of finding the number of males and females hatched, and if the number varied in the different crosses. Owing to unfavourable conditions, bacteria, etc., it was found impossible to get good results. The broods, therefore, are taken in which over fifty per cent of the young came to maturity, and the numbers are given below, together with the broods in which less than fifty per cent survived, and the number of broods which failed entirely.

As a rule, all or nearly all the animals in the small broods survived, probably because they were stronger, as they were certainly larger than the others on hatching. Almost all the very large broods failed in spite of repeated efforts to save them by separating them into several bowls so as to avoid overcrowding, etc.

Of the broods that failed entirely 5 were in the P. × R. cross, 11 in the R. × P., 29 in the H. × R., and 23 in the R. × H., 68 in all.

Broods in which 50 % *and over survived to maturity.*

Black and Red Crosses. ♂ ♀	Number of Broods.	Number Hatched.	Number Survived.	Black.				Red.			
				Males.	Females.	Hatched.	Survived.	Males.	Females.	Hatched.	Survived.
P. × R.	10	106	83	50	33						
R. × P.	25	299	240	129	111						
H. × R.	43	551	387	95	101	282	196	90	101	269	191
R. × H.	37	510	351	92	95	269	187	72	92	241	164

Broods in which less than 50 % *survived.*

Black and Red Crosses. ♂ ♀	Number of Broods.	Number Hatched.	Number Survived.	Black.				Red.			
				Males.	Females.	Hatched.	Survived.	Males.	Females.	Hatched.	Survived.
P. × R.	10	142	31	16	15						
R. × P.	26	492	86	45	41						
H. × R.	43	889	174	46	43	438	89	36	49	451	85
R. × H.	40	860	176	44	36	432	80	55	41	428	96
Black Crosses.											
P. × P.	7	194	79	40	39						
P. × H.	5	57	28	10	18						
H. × P.	9	169	40	17	23						
H. × H.	13	286	30	7	15	220	22	6	2	66	8

RECORDS OF ABNORMAL EYES: "NO-WHITE," "PART-WHITE," AND "ALL-WHITE."

Attempts at breeding the animals together to ascertain if the "no-white," "part-white," and "all-white" variations follow the Mendelian lines of inheritance have so far not succeeded, although these abnormalities seem to run in certain families and not in others. For example, in the F_1 Hybrids (p. 31) a great number of cases occurred in Families A and K, only one case in M, and none in the other families.

Some instances may be given in illustration of the proportions and degree per brood of the "*no-white*" variation. In K family at least six normal-eyed females transmitted this strain, some more than others, and the proportion of "no-white"-eyed in their broods was much higher than in A family. These females mated in the brood-bowl and were removed to extrude their young, and then returned to the bowl to mate again. During the month of June, 1915, 20 broods were extruded by the different K females (some of them having two broods each in the month), and in 10 of the broods "no-white"-eyed individuals were found, as follows :—

14 young :	11 Black,	3 Red ;	amongst them	2 Black	"no-white."
9 ,,	8 ,,	1 ,,	,,	4 ,,	,,
19 ,,	15 ,,	4 ,,	,,	3 ,,	,,
				2 Red	,,
3 ,,	3 ,,	0 ,,	,,	1 Black	,,
15 ,,	11 ,,	4 ,,	,,	6 ,,	,,
28 ,,	23 ,,	5 ,,	,,	1 ,,	,,
				1 Red	,,
30 (2 broods together)	23 ,,	7 ,,	,,	5 Black	,,
				2 Red	,,
17 young :	14 ,,	3 ,,	,,	4 Black	,,
15 ,,	14 ,,	1 ,,	,,	5 ,,	,,

In the A family 7 animals out of the 93 black-eyed (p. 34) produced some "no-white"-eyed young, 1 male and 2 females from Af_2, 1 male and 1 female from Df_2, 1 male from Ef_2, and 1 male from Ff_2. The details are as follows :—

In Exp. 28. Brood III. 1 Black "no-white" on one side, and 1 Red "no-white" both sides. The Black was a female, the Red died before maturity. The ♂ of this experiment mated with the ♀ in Exp. 27 and had 1 Black abnormal ♀ in Brood III.

,, 59. ,, I. 2 "no-white" Black—both died.

,, II. 1 ,, ,, preserved.

,, III. 2 ,, ,, one died. The other was a female "no-white" on right side.

,, 60. ,, II. 1 "no-white" Red male, one side only.

,, IV. Contained 31 young, the eyes in all with very imperfect and broken reticulation.

,, 66. ,, VI. 1 "no-white" Black, female, left side.

,, 93. One brood of 12 young. 1 "no-white" Black, died. All the others with the reticulation imperfect. One brood of 7 young, 5 with imperfect reticulation. One brood of 32 young, all with imperfect reticulation.

,, 112. The male was from Af_2, the female from Df_2.

Brood I. 38 young. 1 "no-white" Black, died. Many with reticulation imperfect. Several Red, very pale colour.

,, II. 2 young. 1 Black "no-white" both sides—died.

Another instance is that of Exp. 99 (p. 38), a Pure Black male from Bf_2 mated with a Recessive female, both with normal eyes. All their young, 86 in number, were also normal. In the F_2 generation the " no-white " and the " part-white " strains appeared in the offspring of a pair from Brood 7. This pair had three broods, the first brood of 6 died young. Of the second brood, 21 in all, 13 Black and 8 Red, only 7 survived, 3 Black males, one with the left eye affected (in this case 2 or 3 of the ommatidia formed a little cluster apart from the ommateum). 4 Red survived, two normal and two " part-white " as figured (Fig. 7). (In the first brood from these Reds 3 out of the 4 young (F_4) had normal eyes, the fourth had eyes like the male figured.) The third brood numbered 30, 20 Black and 10 Red, of these 6 survived, 4 Black and 2 Red, only one normal-eyed amongst them, a Black. Two of the other Blacks were " no-white " on both sides, and the remaining one was normal on the right side, but had a small cluster of ommatidia apart on the left side. Of the two Reds, one was " no-white " on the left side, the other had the white reticulation partly lacking, i.e. partly " no-white."

Many cases have occurred in which the white pigment (instead of being diminished or lacking) is present in excess. This appears to be always accompanied by a diminution of the coloured pigment of the retinular cells, the red, e.g., being hardly perceptible, even with a strong lens showing only as a very pale pink tint, instead of the vivid blood-red of the normal red eye. This variation has been noticed especially in the later generations of the inbred Recessives, and it is possible that another generation or two of inbreeding may produce the " *all-white* " eye.

Only a few " *all-whites* " have been recorded so far (Nov. 19, 1915). Two, a male hatched April 2, 1915, and a female hatched April 14, have appeared in the Pure Red Stock amongst the young from Brood 4, Exp. 5, Recessives (p. 27) (descendants of the fourth brood of female A of the original experiments, p. 22). The female came to maturity but died without mating. The male (Fig. 8) was mated with female B (Figs. 9 and 10), referred to below (a Hybrid with degenerate " white " eyes), and proved pure Red—the 5 young being normal-eyed, 2 Black and 3 Red. It died in moulting, November 19, 1915, without mating again. Two other females from the same brood as the " all-white " female extruded their young in the brood-bowl, 6 in number, all with very pale pink, almost " white " eyes.

A curious instance of the " all-white " accompanied by degeneration of the eye was noted in the forty-second brood of M family, F_1 Hybrids (p. 31). This brood was extruded on June 1, 1915, and numbered 12 young, 7 Black, 1 Red, and 4 " all-white " eyes. These four proved to be 1 male and 3 females. The male mated with one of the females, eggs were laid but thrown off, then the male died and was eaten. A Pure Black male was put in, mated with one of the females, but ate it after mating.

By September 26 only the two females B and C were left. The "all-white" male from the Pure Red Stock with unpigmented perfectly formed eyes (Fig. 8) was put with them and mated at once with female B (Figs. 9 and 10), eggs were laid, and 5 young were extruded, on October 16, all with *normal* eyes, 2 Black and 3 Red. This result proved beyond doubt that female B was a true Hybrid and the male a true Recessive.

The second female, C, was left with the same male, but as no mating had taken place by October 28, a Red male was added, mated, and the eggs were laid on November 4.

The figures given of the eyes and eye-colours are all taken from living animals, for the colours alter so rapidly after death, that notes made on the colour in dead or preserved specimens are not of the slightest value. For instance, the white pigment disappears within an hour or two of death, and the red also fades out completely, though much more gradually.

GENERAL NOTES.

Breeding different generations together.—Eight experiments were made with males of the F_3 generation and females of the F_2: one with R. × H.; two with H. × R.; two with H. × H.; and three with H. × P. In the first, the male was rather small, mated three times, and carried the female for 7, 6, and 6 days respectively with no results; female disappeared. In 2nd Exp. the female was eaten; 3rd Exp., one brood of 26 young was hatched, 11 Black and 15 Red, the male died; 4th Exp., one brood of 6 young; 5th Exp., eggs were laid, not hatched, male died; 6th Exp., same male as in the second experiment, one brood of 5 young, male died; 7th Exp., female laid eggs but died before they hatched; 8th Exp., four broods of 36, 17, 30, 30; male eaten. The results are not satisfactory, probably because of the difference in size. The females were large, and the males had only just reached maturity. When the animals are about the same size there is nothing to distinguish their matings from those of animals of the same generation.

Fertility.—A great variation in fertility has been noticed, not only in individuals, but often in all the members of any one brood.

Some instances may be given in illustration from broods of the F_1 generation of the Recessives. As an example of infertility Brood 1 of Exp. 9, p. 27, may be taken. Ten young were hatched, and most of them reached maturity, but after six months' breeding they all perished without leaving a single descendant. Brood after brood of eggs were laid, but not a single young one was hatched.

Another brood, Exp. 5, Brood 4, kept under the same conditions as the one just mentioned and breeding during the same time had 132 young. In the following four months, March to July, 1915, 91 young were hatched.

The next brood of the same experiment, Exp. 5, Brood 5, shows a curious variation. There were the same number of individuals as in the last, the same conditions, etc. After six months' breeding only 2 young were hatched from all the eggs laid, but in the following three months, April to July, 1915, 90 young were hatched.

For instances of fertility and infertility in individuals some of the F_2 animals may be taken. Sometimes an animal will mate several times with no results; the most striking case of this was the H. female of Exp. 39 (p. 36). Mated with a Black male, eggs were laid on September 12, 1914, carried for six days and then thrown off; eggs again on September 25 and again thrown off before hatching. The male was taken away, and another Black male put in: eggs laid on October 9 and thrown off; eggs again on October 23 and again thrown off. Then the female was left for a period without a male. On November 29 the male was put back, and eggs were laid, a large number, thrown off some days later; eggs laid on December 14, a large number, thrown off; eggs laid on January 3, 1915, all there on January 12, but on the 14th they were all thrown off except two, these were carried a day or two longer but not hatched. The male was taken away, and a Red male put in, which died on January 26 without any mating taking place. Then two more Red males were added —one disappeared on February 8. The female laid eggs, very few, these were thrown off on February 11. The male was again changed. On February 17 eggs were laid, and from these 4 young were hatched on March 8. Eggs were laid on March 10 and 12 young hatched on April 3. A fresh brood laid on April 3, hatched out on April 23, 19 young. The male disappeared and another was put in. Eggs laid on June 1, very few in number. On June 9 the male ate the female. The seven males used in this experiment, 2 Black and 5 Red, were all healthy animals, which had already fertilised the eggs of other females.

Numbers in Broods.—As a rule it is found that an exceptionally large brood of young is followed by a very small brood, or by the omission of one period of sexual activity, but in several cases the animals had a series of large broods, the highest numbers recorded in two succeeding broods being: In Exp. 11 (R. ♀ mated with H. ♂), 42 in the brood and (mated directly after with another H. ♂, Exp. 20) 44 in the next; in Exp. 51 (H. ♀ × R. ♂), 40 and (mated then with H. ♂, Exp. 106) 52, the largest number in a brood yet recorded; Exps. 60, 68, and 104 (H. ♂ × R. ♀) had 47 and 31, 30 and 48, and 40 and 43 respectively, and Exps. 70 and

71 (P. ♀ × R. ♂, and H. ♀ × R. ♂) had 43 and 23, and 41 and 41 respectively, all except Exp. 70 being Hybrid Black and Recessive matings.

Different rate of development.—There is often a marked difference in the rate of development of individuals in the same brood, and also of broods from the same pair. For example, in Exp. 85 (p. 38) some members of a brood hatched on January 6, 1915, were mature in March, the others not till June. Many instances like this were noted.

In Exp. 99, Brood V took four months to reach maturity; Brood VI, seven months; while Brood VII was mature in two months, and the animals were then much larger than many of the broods hatched three months earlier.

It was found that Bacteria greatly retarded growth; in one case a female took eight months to become mature, and was then only about half the normal size.

SUMMARY.

1. Twenty-one thousand, five hundred and fourteen (21,514) amphipods of the species *Gammarus chevreuxi* Sexton have been examined for eye-colour, 21,302 referred to in this paper, and 212 in other experiments, not included.

2. The normal eye-colour of this species is black, with a superficial reticulation of opaque white pigment.

3. The pigmentation of the eye is very variable within limits. Eyes have been observed either partially or entirely lacking in the coloured pigment of the retinular cells, or with either a partial or entire lack, or else an excess of the opaque white pigment.

4. The red strain appears to have arisen as a "sport" in the second generation of offspring of the first animals captured. No red-eyed animals have yet been found in natural conditions, although many thousands have been brought in from time to time and examined. Those counted for the purpose while the work for this paper was in progress numbered 8697, but this figure does not include the many thousands previously observed. Experiments have been made repeatedly with a view of getting the Red strain again from the Pure Black, but with no success.

5. The Red eye-colour is not a sex-limited character; about as many males as females come to maturity. 4248 red-eyed animals have been examined, 4175 referred to in the paper, and 73 in control experiments.

6. The inheritance of the coloured pigment of the eye follows the Mendelian law—Black is dominant and Red recessive. The dominants are divided into Pure Black and Impure or Hybrid Black.

7. The Pure Dominants and the Recessives breed true through all generations.

8. The crosses which have been made and the young hatched from them are as follows :—

Pure Black × *Recessive.*—3779 black-eyed young ; 3746 in paper, 33 in control experiments.

Hybrid Black × *Recessive.*—4255 young, of which 2176 were black-eyed and 2079 red-eyed. Those referred to in the paper numbered 4189, 2138 Black and 2051 Red, the others came from other experiments in the F_4 generation—not included.

Pure Black × *Pure Black.*—All black-eyed young, 1715 in number.

Pure Black × *Hybrid Black.*—All black-eyed young, 379 in number.

Hybrid Black × *Hybrid Black.*—4393 young, of which 3327 were black-eyed and 1066 red-eyed. Those referred to in the paper numbered 4302, 3259 Black and 1043 Red—the other 91, being from the F_4 experiments, not included here.

9. The absence or diminution of the white pigment seems peculiar to some broods. The "*no-white*" eye appeared in the second generation of offspring of Pure Black animals brought in from the ditches. The individuals affected in this way are more difficult to rear than the others, and, so far, attempts to breed them have not been successful.

10. The absence of the coloured pigment and degeneration of the eye occurred also in the F_2 generation—in this case from Hybrid Black animals.

11. The absence of the coloured pigment in perfectly formed eyes, the "*all-white*" eye, occurred in the Recessives. A great diminution of the red pigment has also been observed, particularly in the F_4 generation of the inbred Recessives.

12. The absence of the coloured pigment in part of the eye, the "*part-white*" eye, was observed in the first generation of offspring of Pure Blacks brought in from the ditches. It has been noted several times in both black and red eyes of specimens bred in the Laboratory, but only once in fresh-captured material. This case was a male, with one eye affected.

13. About as many males as females survive to maturity.

14. The breeding together of animals from different generations gives the same results as regards proportions of colours as the breeding together in the same generation.

EXPLANATION OF PLATE I.

FIG. 1.—Pure Black eye. Female from Brood 1 of Exp. 118 (p. 41). Extruded June 9. Mated with Red male, first brood hatched Aug. 26 numbering 14; five more broods, 19, 31, 24, 41, and 36 respectively, all black-eyed. Figured Oct. 29, 1915, a few hours before moulting. × 58.

FIG. 2.—Hybrid Black eye. Female from Brood 7 of Exp. 105*b* (p. 41). Extruded April 29, figured Nov. 24, 1915. Mated with H. male, one brood of 13, 10 Black and 3 Red. × 58.

FIG. 3.—Red eye. Large male from Recessive stock. Figured Nov. 5, 1915, two days before moulting; examined after moulting but no increase of ommatidia seen. × 58.

FIG. 4.—Right eye of young Hybrid from H. × R. cross. Extruded Oct. 22, figured Oct. 25, 1915; the white pigment was then much more solid in appearance than when newly hatched. × 75.

FIG. 5.—Right eye of young Red from Recessive stock. Extruded Oct. 21, 1915, and figured three hours after extrusion. × 75.

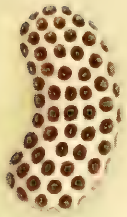
FIG. 6.—"No-white" eye. Young male from the second generation of Pure Blacks (p. 25). Figured Nov. 23, 1915. × 58.

FIG. 7.—"Part-white" eye. Male. F_2 generation from P. × R. cross (see p. 45). Extruded June 15. Figured Nov. 2, 1915. × 58.

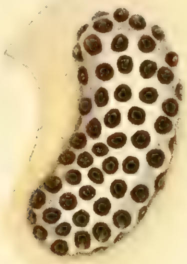
FIG. 8.—"All-white" eye. Male from inbred Recessive stock (see p. 45). Extruded April 2, died in moulting and figured Nov. 19, 1915. × 58.

FIG. 9.—"All-white" degenerate eye, right side. Female B. F_2 generation from P. × R. cross (see p. 46). Extruded June 1, figured Nov. 16, 1915. × 58.

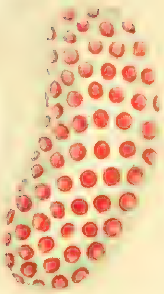
FIG. 10.—"All-white" degenerate eye, left side, from Female B. Figured Nov. 16. × 58.



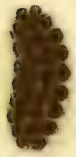
2



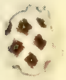
1



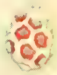
3



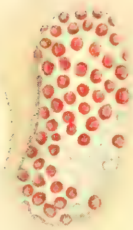
6



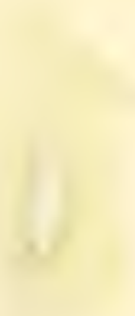
4



5

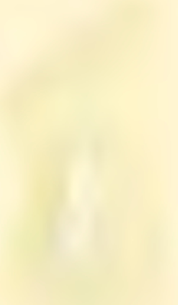


7



9

8



10

E. W. Sexton del.

Notes on the Life History of *Anaphia petiolata* (Kröyer).

By

Marie V. Lebour, M.Sc.,
Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist at the Plymouth Laboratory.

With Figures 1 to 3 in the Text.

In the early summer of 1915 it was noticed that many medusæ brought in with the tow-nettings contained larval Pycnogonids in the manubrium and at the junction of manubrium and stomach. The medusæ specially noticed to contain them were *Obelia* sp., *Cosmetira pilosella*, *Turris pileata*, *Stomotoca dinema* and *Phialidium hemisphericum*. By far the greater number were in *Obelia*, although many were in *Phialidium hemisphericum* and *Cosmetira pilosella*. They were extremely abundant in June, after that became scarcer, and finally disappeared by October. On examination they were seen to be larval stages of *Anaphia petiolata** (Kröyer), a Pycnogonid common in Plymouth Sound. The older larvæ sometimes were seen to cast their skins, so that the species could be easily recognised, although the fourth pair of walking legs were not fully developed. This is evidently the species described by Dogiel (1913) as *Anoplodactylus pygmæus*, the life history of which he traces from its first entry into the *Obelia* hydroid to the older stages when it is ready to leave its host. The form he refers to as *Anoplodactylus petiolatus* occurring in cysts in *Coryne* with *Phoxichilidium femoratum* must be some other species, as his figures prove clearly that it differs from *A. pygmæus*, and also the colour is totally different (a bright pink, while the present form is a pale yellow). Dogiel believes he has proved that *Anoplodactylus petiolatus* and *A. pygmæus* are different species from the difference in their life histories, and it is evident that he is dealing with two different species, but his *A. petiolatus* cannot be the same as our form, which is certainly identical with his *A. pygmæus*, and shows that Sars (1891) and Norman (1894) were right in regarding *A. pygmæus* as the young form of *A. petiolatus* (Kröyer).

---

* This is a synonym of *Anoplodactylus petiolatus* (Kröyer). See Norman, 1908, p. 202.

Dogiel's account of the larval stages of *A. pygmæus*, together with the present discovery of the older larvæ in medusæ, shows a most interesting life history. According to him the very young larva hatches out of the egg (which contains very little yolk), leaves the protection of the father, and crawls on to the *Obelia* hydroid. In this early stage it has three appendages, the first the chelæ, the second and third with long thread-like ends which are used for attachment to the father directly after hatching. It immediately begins to burrow into one of the hydroid polyps, and once settled down there undergoes a metamorphosis, the second and third appendages atrophy, and three pair of walking legs develop. After several moults older larvæ appear, which are like the adults, except for the incompleteness of the last pair of walking legs, and these leave the hydroid and begin to live a free existence.

The stages found in the medusæ correspond to the larval stages after the second and third appendages have atrophied. The youngest stage seen corresponds with Dogiel's Stage IV with the three pair of walking legs indicated and the chelæ well stretched out in front, which are used for clinging firmly to the host. Dogiel has called attention to the fact that many larvæ do not succeed in entering the polyps, and have to undergo their development on and not in the hydroid, and now we find still another alternative for the larva. A large proportion of them, instead of entering a polyp, must in some way manage to enter a medusa. How they do this it is not possible at present to say. Possibly they cling to a medusa just as it is escaping from the colony, or perhaps they may get into a gonotheca before the liberation of the medusæ. One young larva in just the same stage as the youngest from a medusa was found amongst a colony of *Obelia* from Laminaria collected below the Laboratory. The occurrence of the same larva in various medusæ shows that it does not strictly keep to one species or genus of hydroid, although *Obelia* seems to be the favourite host.

The discovery that larval Pycnogonids are carried about by medusæ must have an important bearing on their means of dispersal, those individuals which are in the medusæ having much greater chances of life than those in the crowded area where the hydroid colony is situated. Pycnogonids swim feebly, and have not much in themselves to help in their distribution (see Calman, 1915, p. 6), but in the parasitic habits we have an important means of dispersal. Already H. Merton (1906) has found a species of nymphon (*N. parasiticum*) living parasitically on the nudibranch *Tethys leporina* in the Mediterranean. H. Prell (1909) has found nymphon on Lucernaria (in this case eating the tentacles), now we find larval forms being carried about in medusæ. It is interesting to note that a young specimen of *Endeis spinosus* (Montagu) was twice found in the tow-nettings from outside the Breakwater, Plymouth, extended flat on the top of the bell of an *Obelia* medusa, and clinging to it. So beautifully was it balanced that the medusa could swim perfectly, although weighted by the Pycnogonid.

If medusæ and Pycnogonids are left together in a vessel, e.g. *Anaphia petiolata* or *Endeis spinosus*, it is nearly always found that the Pycnogonids are attracted towards the medusæ and cling to them. The only movement made by the young larvæ when taken from the medusæ is a strong waving of the chelæ, and if these come in contact with a medusa they cling tightly to it.

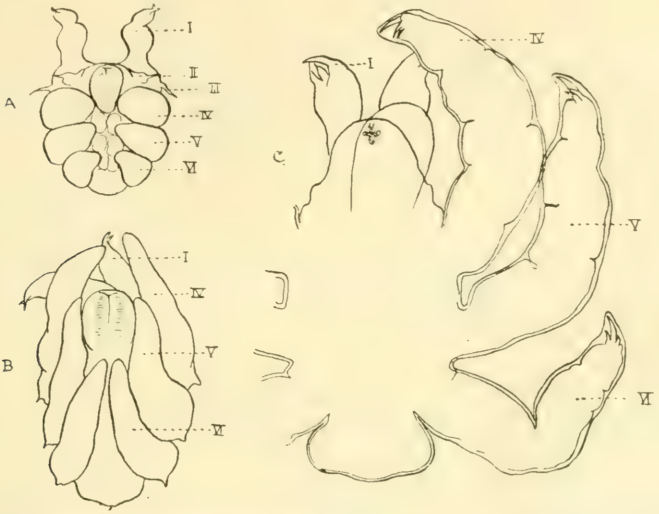


FIG. 1.—Larval stages of *Anaphia petiolatus* (Kröyer). × 60. A. Youngest stage in *Obelia* medusa; B. Later stage; C. Still later stage, the legs having been separated with needles. I–VI. The appendages. Ventral view.

The larva at all stages is of a pale yellow colour, and has its legs so folded that they pack into the smallest possible space. As many as four were found in one medusa, but usually there is only one. It grows rapidly, and the body elongates considerably together with a great lengthening of the legs. In the youngest stage found (Fig. 1, A) the legs (IV–VI) were short, roundish stumps, the alimentary canal extending into them and well into the chelæ. The chelæ were powerfully developed with strong claws; remains of the second and third larval appendages were seen as small hair-like protuberances. These, however, are often very difficult to see, and the drawing shows an exceptionally clear specimen. These appendages, although dwindling, persist until the larva has grown to nearly twice the size; in this differing from Dogiel's observations, who describes them as disappearing almost at once.

As the legs elongate a short spine is apparent at the angle of folding, but these soon disappear (Fig. 1, B). When considerably larger the larva resembles the adult, although still packed up tight. If the legs be unfolded the body is seen to be broad with the cephalic segment distinct, proboscis fairly long, the claws of the legs showing through the skin, and the last pair of legs and caudal segment appearing as a broad hind piece (Fig. 1, C). Yellow eyes have now appeared. This is the last larval stage, which shows the young *Anaphia* through the skin, and this form can often be seen with the young *Anaphia* emerging from it. This is in all essentials like the adult, but much smaller, and with the last pair of legs appearing as two stumps with a very short caudal segment in between them. When quite newly hatched it measures about 0·70 mm. from the anterior end of the cephalic segment to the posterior end of the caudal segment (Fig. 2). The cephalic segment is very short, in fact the whole animal is exactly like the figures and descriptions of *Anoplo-*

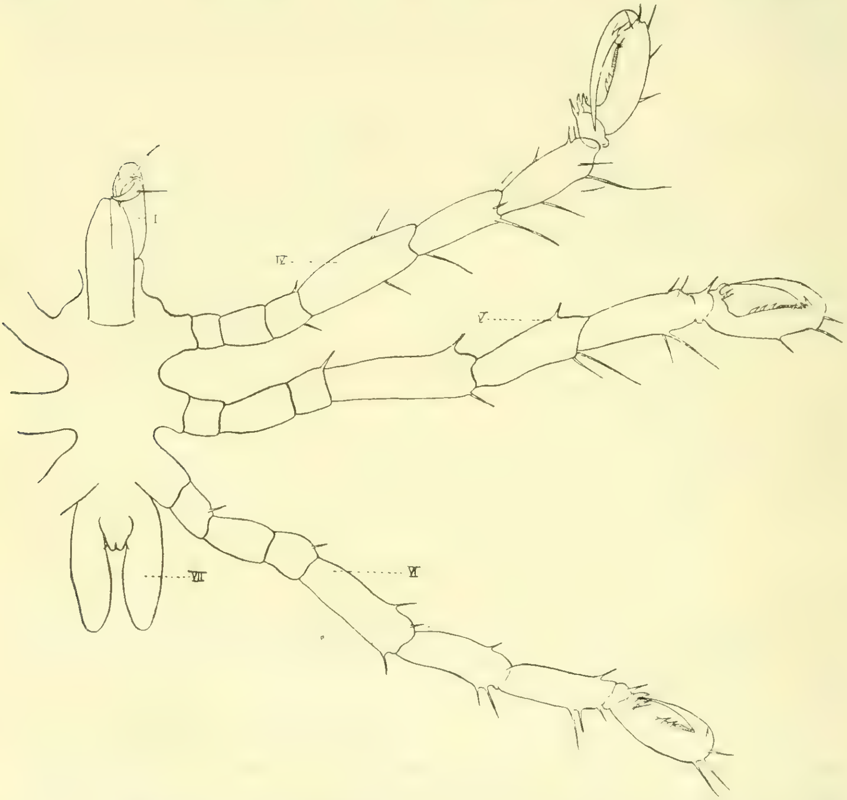


Fig. 2.—Young *Anaphia petiolata* (Kröyer) soon after emergence from the last larval skin. Lettering as before. × 47.

dactylus pygmæus (Hoek, 1881; Hodge, 1864). By comparing these young forms with older undoubted specimens of *Anaphia petiolata* (Kröyer), they correspond exactly with the exception of the length of the cephalic segment, which grows with the animal just as Canon Norman suggests (1894). The growth, however, appears to take place after the moult in which the walking legs are complete, that is to say when the body and legs are fully formed, for a series of measurements show that there is very little difference in the length of the cephalic segment of the young form after it has sloughed its last larval skin and the young form with completely formed legs (see Fig. 3). The increase in length takes place afterwards.

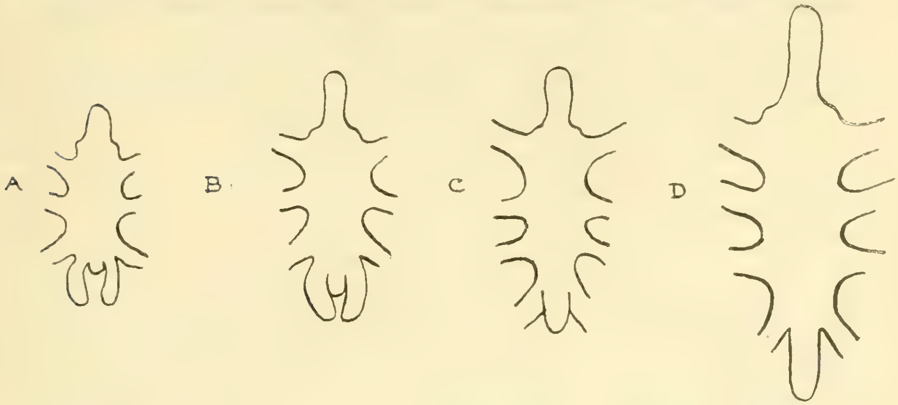


FIG. 3.—Diagram to show growth of cephalic segment. A. Length 0·70 mm., young *Anaphia petiolata* directly after emergence from the last larval skin; B. Length 0·90 mm., later stage; C. Length 1·04 mm., later stage in which all legs are developed; D. Length 1·56 mm., nearly full grown.

LITERATURE.

1915. CALMAN, W. T.—Pycnogonida. British Antarctic ("Terra Nova") Expedition. 1910.

1913. DOGIEL, V.—Embryologische Studien an Pantopoden. Zeitschrift für Wissenschaftliche Zoologie, Bd. 107, pp. 575–741.

1864. HODGE, G.—List of the British Pycnogonoidea with Descriptions of Several New Species. Annals and Magazine of Natural History. Feb., 1864.

1881. HOEK, P. P. C.—Nouvelles Etudes sur les Pycnogonides. Archives de Zoologie Expérimentale et Générale, pp. 445–542.

1906. MERTON, H.—Eine auf Tethys leporina parasitisch lebende Pantopodenlarve (Nymphon parasiticum, n. sp.). Mittheilungen aus der Zoologischen Station zu Neapel, Bd. 18, pp. 136–41.

1894. NORMAN, CANON A. M.—A Month on the Trondhjem Fiord. Annals and Magazine of Natural History, Ser. 6, Vol. XIII. Feb., 1894.

1908. Ibid.—The Podosomata (=Pycnogonida) of the Temperate Atlantic and Arctic Oceans. Journal of the Linnean Society, Zoology, Vol. XXX, pp. 198–238.

1909. PRELL, H.—Beiträge zur Kenntnis der Lebensweise einiger Pantopoden. Bergens Museums Aarbog, 1909. No. 10.

1891. SARS, G. O.—Pycnogonidea. Norwegian North Atlantic Expedition, 1876–78.

Medusæ as Hosts for Larval Trematodes.

By

Marie V. Lebour, M.Sc.,
Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist in the Plymouth Laboratory.

With Figure 1 in the Text.

THE larval form (late cercaria stage) of *Pharyngora bacillaris* (Molin) has been recorded by Nicoll (1910) from Plymouth as occurring free in the coarse-meshed tow-nettings in August. The adult is a common parasite of the mackerel, and the above is the only record of its larval stage.

Whilst examining tow-nettings at Plymouth in 1915 it was found that certain medusæ were at times abundantly infected with a trematode which proved to be the larval form of *Pharyngora bacillaris*. As it also occurred free, although almost certainly having originally come from the medusæ, it is obviously the form recorded by Nicoll, who expected the host to be a crustacean and unsuccessfully examined copepods in order to find it.

The medusæ found to contain the trematode were *Obelia sp.*, *Cosmetira pilosella*, and *Turris pileata*. *Cosmetira pilosella* was the commonest host in the early summer when Pharyngora was most abundant, but in the later summer Obelia was found to contain it frequently, Cosmetira not occurring at those times in the tow-nettings. *Phialidium hemisphericum* was also a host in the later summer and autumn. Even in December it still occurred, though very rarely. A ctenophore may also serve as host for this trematode, as it is occasionally found clinging to the inside of the stomach of *Pleurobrachia pileus*.

The parasite is generally to be found clinging to the manubrium or stomach wall of its host, but sometimes it occurs underneath the umbrella wall, so that it looks as if it were on the top, the wall being so transparent; on further examination, however, it is seen to be underneath. It seems to be undoubtedly a case of parasitism as so many of the medusæ were infected, sometimes every specimen in a haul, and, with the exception of an occasional ctenophore, none of the other animals in the same haul contained them or had them clinging to them.

From these observations it seems that there is no encysted stage in this species, the period passed in the medusa serving the same purpose. Probably this period is very short, the mackerel swallowing the host soon after the entry of the parasite, and for this reason an encysted stage is not necessary.

Nothing is at present known of the early stages in the life history of Pharyngora, although it is to be inferred that a mollusk is the first host.

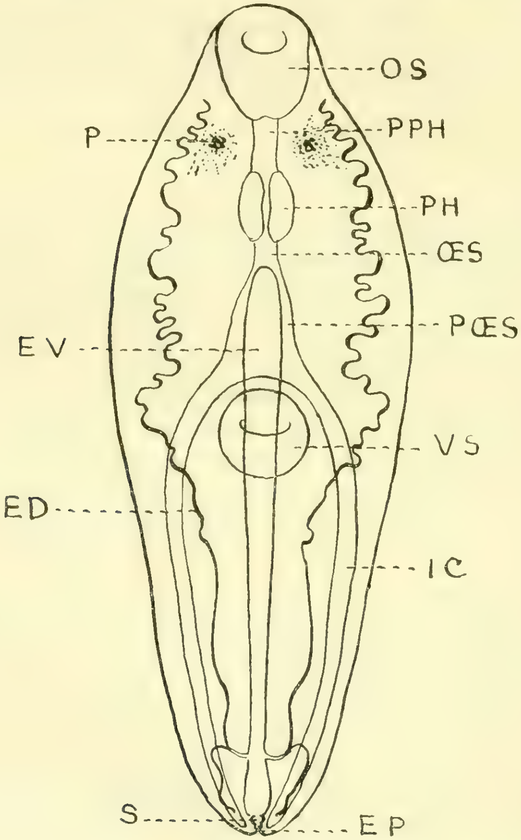


FIG. 1.—*Pharyngora bacillaris.* × 120. ED, excretory duct; EP, excretory pore; EV, excretory vesicle; IC, intestinal cæcum; ŒS, œsophagus; OS, oral sucker; PH, pharynx; PPH, prepharynx; PŒS, pseudo-œsophagus; VS, ventral sucker.

The larval worm is very like the adult, but without reproductive organs (see Fig. 1), and bears a close resemblance to Nicoll's figure (Plate XXIX, Fig. 5). The body is covered with minute spines; the curiously shaped oval sucker is conspicuous; ventral sucker, prepharynx, pharynx, œsophagus, pseudo-œsophagus, and intestinal cæca all agree with the adult form. The body in this stage, however, is crowded with gland cells along the sides reaching from the pharynx to well behind the ventral sucker. The pigment spots anteriorly are very well developed. The excretory vesicle is long and narrow, just as Nicoll describes it, its ducts in the larval form showing particularly clearly. At the hind end is a strong sphincter guarding the opening posteriorly; in front of this the main excretory branches are given off which send one branch backwards and a much convoluted branch forwards. The flame cells are particularly well seen in the living larval forms. As Nicoll's description does not enter into the details of the excretory system a figure of the larva is given, showing the main points.

REFERENCE.

1910. Nicoll.—On the Entozoa of Fishes from the Firth of Clyde. Parasitology, Vol. III, No. 3.

Notes on the Œcology of *Cirratulus* (*Audouinia*) *tentaculatus* (Montagu).

By

F. W. Flattely,

University College of Wales, Aberystwyth.

With Figures 1 to 7 in the Text.

Cirratulus tentaculatus is found inhabiting the wet, sandy, somewhat foul mud of the Aberystwyth shore, chiefly in the Laminarian zone, although it also occurs in rock pools higher up the shore in which there is sufficient depth of sand containing the necessary organic matter. The presence of the worm in its natural habitat is indicated by a group of delicate, elongate, rosy or yellow coloured filaments of tentacular appearance which protrude from the sand into the pools left by the receding tide. These filaments nearly always display a certain amount of movement, either waving gently from side to side or curling slightly from the tips. The amount of motion and also the colour of the filaments will depend on the degree of freshness of the water in the pool, and this, of course, will, in its turn, be related to the state of the tide.

Specimens are not easy to collect owing to the marked propensity the animal exhibits for lying with its body beneath stones or pieces of rock embedded in the mud. In rock pools or crevices where there is but little depth of sand and the animal lies with its body more or less parallel to the surface collection is almost impossible. This response to stimuli of contact and pressure, or, as M. Georges Bohn has it, this " thygmotactism," is very marked, and, in the aquarium, when specimens are placed in a vessel containing sand and a few stones, the animals will roam about till some portion, at any rate, of their bodies is undergoing pressure from those stones.

Thus, in addition to the occurrence of sandy mud of rich organic content, the worm would seem to require the presence of a certain amount of rock or loose stones. Both these requirements are well met on the portion of the Aberystwyth shore opposite the College. Here a large reef of rock runs out to sea in such a manner as to form a barrier to the prevailing wind and thus to aid in the deposition of organic matter, of which no doubt a certain proportion is contributed by the Harbour sewer lying to southward, decaying fragments of algæ, etc.

When withdrawn from the mud Cirratulus presents an exceedingly limp and bedraggled appearance. The body appears to possess, when in this partially extended condition, absolutely no turgidity. This is in agreement with the animal's marked thygmotactism, the necessary tension being secured in the natural habitat by the pressure of stones.

A detailed account of the external characters is no longer necessary, owing to the recent appearance of Vol. 3 of Prof. McIntosh's memoir on British Marine Annelids, containing the Cirratulidæ (1). It is sufficient to say that the species *tentaculatus* is distinguished by the occurrence of lateral filaments on segments anterior to the fifth chætigerous segment behind which the paired fascicles of filaments arise.

Considerable doubt seems to exist as to the analogy of the lateral filaments with those of the paired tufts. Prof. McIntosh quotes Claparède as distinguishing (in *C. chrysoderma*) between tentacles and branchiæ in such forms by the fact that the former have only one blood-vessel, whilst the latter have two. In *Audouinia filigera*, on the contrary, every filament is branchial in structure. De St. Joseph (2) distinguishes between Cirratulus, in which the tentacles appear at the same time as the branchiæ, and Audouinia, in which the segments bearing the tentacles are preceded by a variable number of segments with lateral branchiæ, and remarks that in neither case do the tentacular filaments and lateral branchiæ differ materially in external appearance. Cunningham and Ramage (3), on the other hand, describe a groove along the so-called tentacles and find it to contain only a single blood-vessel, whereas in the branchiæ two blood-vessels are present.

J. Bounhiol (4), in an ingenious paper on Respiration in Polychætes, denies any respiratory function to either kind of filaments; he says if a specimen of either *Cirratulus cirratus* or *C. tentaculatus* be placed in a glass vessel the floor of which is covered with sand, the animal is soon seen to make active use of the tentacular filaments to remove the sand grains, draw them towards itself and more or less cover itself with them. These filaments have been placed by anatomists in two categories, according to whether they contain a simple vascular cæcum or a complete vascular circuit. The first are called tentacular filaments, the others gills. But the animal uses both kinds indiscriminately as prehensile organs. It has also been shown by experiment that the respiratory rôle of these so-called gills is very feeble, and merely corresponds to an increase of the body surface. "La définition anatomique des branchies de Cirratulidæ n'est donc pas confirmée par l'expérimentation physiologique. Ce sont de simples organes prehensiles, tout comme les filaments prehensiles dont on avait cru pouvoir les distinguer."

The experiments of M. Bounhiol on Cirratulus in his examination of the filaments as respiratory organs were faulty as they made no allowance for the animal's natural habitat. The rôle played by the filaments is essentially respiratory; further, close observation has shown that the prehensile function, so readily admitted by most authors, is non-existent. Careful study of the animal's habits shows that there is absolutely no need for such a function, whereas there is every need for that of respiration. What leads the majority of observers to suppose a prehensile function is undoubtedly the perpetual curling motion of the filaments in the pools. A differentiation of function between the lateral filaments and those in the paired fascicles is undoubtedly suggested by their behaviour when the animal is withdrawn from the mud. The filaments in the clusters immediately contract, their colour becoming quite yellow, while the remaining lateral filaments are still more or less distended by the contained blood, and are, of course, red in colour. These superficial differences, however, do not necessarily prove any difference in function, and this notwithstanding the disparity in structure referred to by Bounhiol. [It has been suggested that the fascicles of filaments are prostomial tentacles which have shifted backwards, Meyer (12)]. The worm is essentially and in all except perfectly abnormal conditions a burrower, and consequently permanently subject to pressure. When all pressure is relaxed and the animal bathed on all sides by water it is only natural that, with respiration taking place over the whole body surface, numbers of filaments should be left idle, and it would be particularly the filaments lying in front of the heart-body which would be affected. In further response to the relieved pressure the animal contracts and curls up, the anterior part of the body is forced beneath the coils and the prostomium is protruded as far as possible, and the characteristic actions of burrowing are performed, that is to say, the anterior region is pumped turgid with fluid and waves of muscular contraction pass along the body from behind forwards. At the same time the mucous investment, with the sand adhering from the burrow, is gradually shed and becomes caught in the gill filaments, and an inextricable tangle is the result. Prof. McIntosh notes that the animal appears to be less comfortable in pure sea water, and thinks the mud to be the most fitting medium, since it keeps the filaments apart. Undoubtedly, mud is a more fitting medium, but not, I think, for this latter reason. If a number of flat stones be laid upon the bottom of the vessel, the worm, a few hours later, will be found ensconced beneath them and numbers of filaments will stretch in all directions, without any trace of entanglement, showing that what the animal chiefly lacks is pressure.

The appearance of the gill filaments when the worm is in its natural habitat is sufficiently familiar, but the manner in which they attained that position, in view of their extreme delicacy, is rather remarkable. If the worm be withdrawn from the mud on the floor of the pool and left on the surface, it will immediately coil up and commence to burrow again in the manner already noticed. Owing to the downward and forward movement the gill filaments will tend to stream backwards, and, as the worm progresses, being extremely elastic, their distal portions will remain at the surface, the filaments stretching till the animal has found its proper level. The portions of the filaments remaining in contact with the water will thus be available for aeration of the contained blood.

The question now arises as to how the animal would react should the filaments become buried beneath several inches of mud, as must often happen.

In order to answer this question a specimen of Cirratulus was placed at the bottom of a glass vessel 5 inches high by 2¼ inches in diameter, covered with mud to the height of two inches, and the remainder of the vessel filled with water. Four hours later a number of filaments were projecting at the surface. The following day, when about 20–30 filaments were projecting, another 2½ inches of mud were added. Two hours later one filament had been protruded. This time, by a lucky chance, the anterior end of the worm was in contact with the glass close to the top of the first layer of mud, and its behaviour could thus be observed. The body of the worm itself was practically stationary, some of the filaments of the anterior fascicles were yellow and motionless, but numbers which were gorged with blood showed remarkable activity, and were gradually yet speedily forcing their way upward through sand and mud to the surface, exactly as if they were so many individual worms. The extensility and muscular activity of the filaments is therefore enormous, the length of some of them from their junction with the body wall to the tips exceeding three inches.

The whole forms a remarkable adaptation to an underground habitat. The majority of species of Polychætes inhabiting the same environment are either of small size and able to respire through the body wall generally, or they are obliged to mount to the surface to avoid asphyxiation. Cirratulus is able to live permanently surrounded by the sandy mud where it finds its food supply (reference to which will be made later), and by remaining constantly underground is well protected from enemies. The large numbers in which Cirratulus occurs is sufficient proof of its success.

We have seen that when the body of the worm is undergoing pressure the filaments are stimulated to great activity by the pressure of blood in their vessels, and on seeking an explanation of this phenomenon, we cannot help being struck by the fact that in the Cirratulidæ, the heart-body, the function of which has aroused so much curiosity, reaches its greatest development.

The structure and function of the heart-body, in this and in other groups where it occurs, has been discussed by L. J. Picton (5) and, several years previously, by J. T. Cunningham (6). Although the former writer is chiefly concerned with the composition of the granules contained in the cells forming the body, and of their reaction to various stains, his object being principally to examine its claims as an excretory or blood-controlling organ, he nevertheless gives a certain amount of attention to its possible mechanical function. He quotes the suggestion of Schaeppi (7) in the case of Ophelia and of Steen in that of *Terebellides Stroemii* to the effect that the organ has a valvular function. Schaeppi considers this is brought about by the swelling of the organ at systole owing to the pressure of blood in its meshes. The most telling evidence in favour of a mechanical action is that afforded by *Cirratulus chrysoderma.* Picton says that in this species, which is transparent, the heart-body at the point of its greatest development almost entirely blocks, at systole, the lumen of the heart, the action of which as a blood-propelling organ must be considerably modified.

It seems certain from what has been noted of the habits of Cirratulus that it depends to a great extent amid its somewhat foul surroundings, for its supply of oxygen, on the long filaments. There is, therefore, every necessity, in view of their delicate nature, for maintaining them turgid. Otherwise, they would be extremely liable to breakage and laceration. This difficulty would be met by the heart-body acting as a valve and preventing the blood from being regurgitated. It is certainly remarkable that in Arenicola, to which genus the above arguments apply with almost equal force, the heart-body is also strongly developed. J. H. Ashworth (8) also suggests a valvular function in this latter, and the fact that the organ does not appear till after the pelagic larval and post-larval stages are complete is not without significance. Some such arrangement would be a small compensation for the drawbacks to which Arenicola, with its delicate branched gills, must undoubtedly be exposed, through its sandy environment.

External processes with respiratory properties are a common feature in Polychætes, but that does not necessarily imply the same need for a heart-body, with the function described, in all. According to Picton a heart-body is found in the following groups : Spionidæ, Cirratulidæ, Terebellidæ, Ampharetidæ, Amphictenidæ, Chlorhæmidæ, Sternaspidæ, and Hermellidæ. He omits the Arenicolidæ, and states that in Magelona the organ is merely larval and transitory. As regards the Spionidæ, I am unable to find any confirmation as to its occurrence in this group. Possibly owing to a revision of the nomenclature the Cirratulidæ have been included twice in this list, under different headings.

M. Georges Bohn (9) shows how among Annelids adaptation to life in the sand is pushed further in some groups than in others, and divides the Polychætes, after excluding the Errantia, into three classes, according to the degree in which they have become adapted to a subterranean existence. In connection with this it is interesting to note that it is only in his third group, i.e. among those in which the burrowing habit is the rule, that the heart-body is present, and that all possess delicate respiratory filaments. Bounhiol, to whose paper reference has already been made, belittles the value of these processes for respiration, but the point is that they are not merely of value as gills pure and simple, but are often the seat of abundant cilia which ensure the circulation of water round the body itself. Thus in tubicolous forms serious damage to the processes is as dangerous as in Cirratulidæ or Arenicolidæ. In the Sabellidæ, which do not possess a heart-body, aeration of the body in the tube is obtained by the perpetual protrusion and retraction of the branchial crown, and here the branchiæ or tentacles are no longer soft and delicate, but are supported by an undoubted skeleton, whereas in the closely allied Hermellidæ, e.g. Sabellaria, where a heart-body is present, the " tentacles " and neuropodial processes are again of the delicate type.

GROUPS POSSESSING A HEART-BODY.

Family	*Habits.*	*Type of branchiæ.*
Cirratulidæ.	Permanent burrowers; with exception of one boring form.	Gills soft, delicate, and filamentous, capable of great elongation.
Terebellidæ.	Forms building tubes of sand or mud.	Gills, situated at anterior end, branched in most species, but all soft and delicate.
Ampharetidæ. Amphictenidæ.	Tubicolous.	Gills, situated at anterior end, delicate and filiform, capable of extension, e.g. *Pectinaria belgica*.
Arenicolidæ.	Permanent burrowers.	Gills branched and delicate.
Chlorhæmidæ.	Burrowers or inhabitants of tubes in mud.	Gills delicate and filiform.
Sternaspidæ.	Burrowers.	Gills delicate and thread-like.
Hermellidæ.	Tubicolous.	Filaments at anterior end are apparently not much used for respiration, but true branchial processes are present on the sides of the body. These are delicate, unbranched and covered with cilia.

The above table shows considerable similarity in the nature of the gills and habitat among the species of those families which possess a heart-body. The majority are burrowers, permanently subjected to pressure, and even in the tubicolous forms, seeing that they must often become sanded up (for instance, by wave shock when the tide is rising), the possession of a heart-body cannot but be advantageous in preventing regurgitation of the blood to the dorsal vessel, keeping the branchial processes turgid, and generally counteracting the effects of varying pressure. As a proof of this we note that the greatest development of the heart-body occurs in just those groups where burrowing habit and branchial development are carried to their greatest extent.

It is perhaps advisable to point out here that any mechanical function which is suggested on behalf of the heart-body is only regarded as secondary. There seems hardly any doubt that in the heart-body we are dealing with a structure the original function of which was almost, if not entirely, organic.

It may be urged that, according to this theory, one might reasonably expect to find the development of a heart-body in those other groups of M. Bohn's where the burrowing, free-swimming, and crawling habits are combined, e.g. in the Aphroditidæ, Phyllodocidæ, Nephthydidæ, Glyceridæ, Eunicidæ, Ariciidæ. In these groups, however, apart from the fact that, owing to their semi-active habits, the danger of asphyxiation is considerably reduced, the branchial processes themselves are in most cases effectively protected by the great development of the parapodia and chætæ. This is excellently exemplified by the condition in Nephthys, where the sickle-shaped gill is situated between the strongly developed lobes of the parapodia and their lengthy chætæ.

As we pass to the consideration of forms with more and more predominantly burrowing habit we note the concurrent reduction in size of the chætæ, for, useful as they undoubtedly are in swimming and crawling, they can only be a hindrance to progress in and through sand. The bristles acquire more and more the character of short hooks, enabling the animal to grasp the side of its burrow, and, if the gills are to be retained, a new method of protection must be adopted.

METHOD OF FEEDING.—I will now examine the specialised method of feeding in Cirratulus in more detail. Unlike its congener in the same habitat, Arenicola, Cirratulus does not live by passing sand through the gut; selection of the nutritive organic particles is made outside the body. The excreta are green in colour, and the worm's diet would seem to consist of algal spores, fragments of decaying algæ, diatoms, and general organic debris. In preparing the worm for sectionising no special precautions were taken to ensure the emptying of the gut, and the razor did not suffer.

The best proof of the microscopic nature of the animal's food is the ciliated condition of the gut. It remains to be seen by what means the animal is able to exercise selection.

On the ventral side of the peristomium a deep groove leads back to the mouth and is continuous with the dorsal surface of the gut. On the walls of the pharynx immediately behind the mouth opening are situated a pair of flaps. These flaps are dorso-lateral in position and project each with its free edge standing out ventrally towards the median line (see Figs. 1–7).

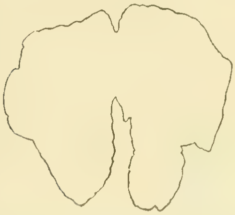


Fig. 1.—Transverse section through the anterior portion of the peristomium, showing the ventral groove.

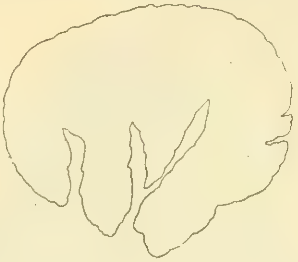


Fig. 2.—Transverse section behind Fig. 1, showing the development of the sensory flaps.

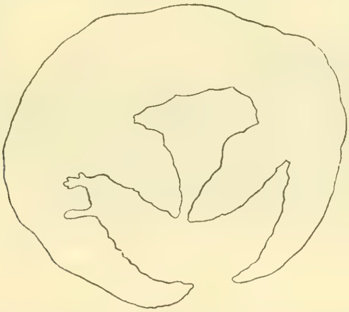


Fig. 3.—Section through the peristomium, somewhat anterior to the line AB in Fig. 7.

The two free edges are closely apposed and thus practically separate a groove above them from the remainder of the vestibule beneath. The epithelium of this groove and of the surfaces of the flaps which face inwards, including the free edges, is ciliated and rich in sensory elements, and is most markedly distinguishable from the general epidermis and from the lining of the vestibule, the floor of which projects forwards and seems glandular. The ciliated epithelium of the gut has already been noticed. The animal would thus seem to feed by a kind of suction; the sensitive edges of the flaps being closely apposed would effectively prohibit the entrance of any but the smallest food particles, and these latter would be wafted backwards by the cilia of the gut epithelium.

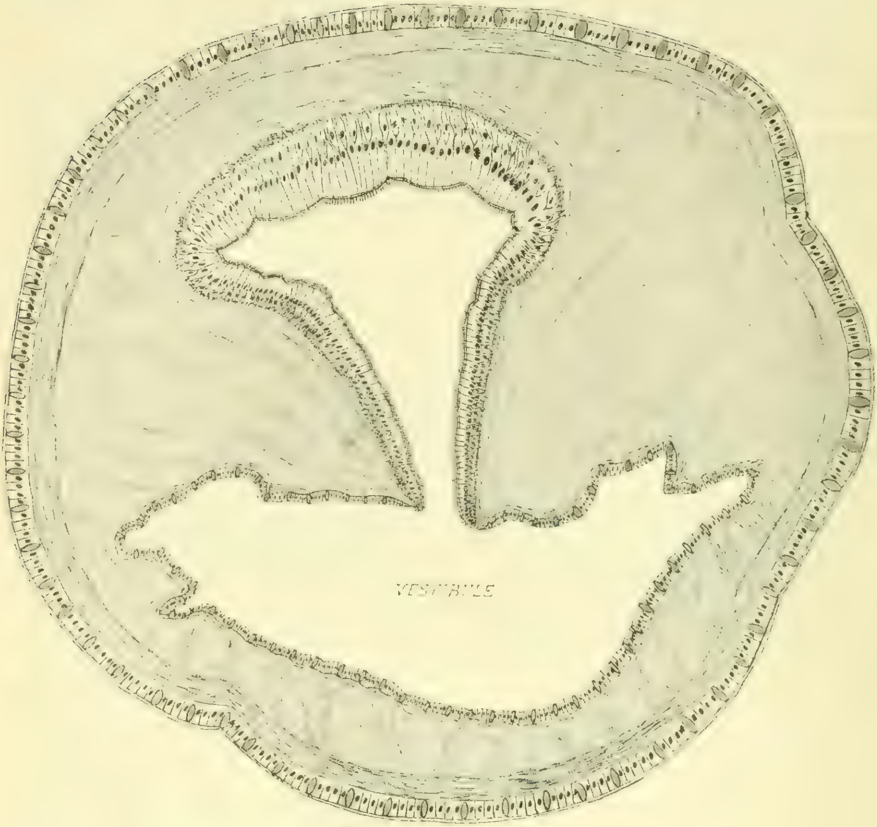
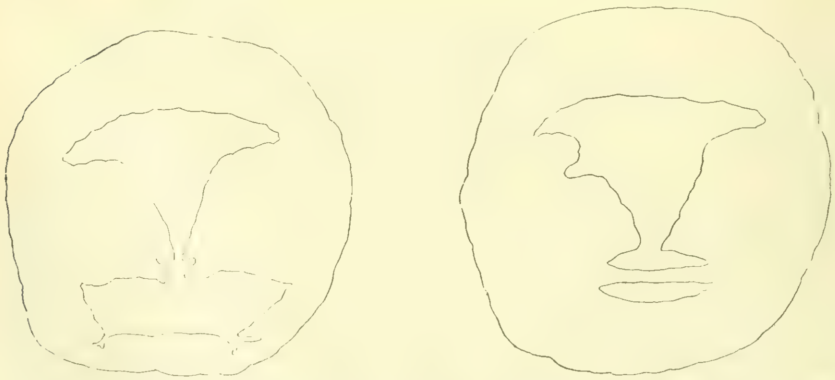


Fig. 4.—Transverse section through A–B in Fig. 7, showing the sensory lips and the ciliated epithelium of the gut.



Figs. 5 and 6.—Sections showing the gradual disappearance of the vestibules and the fusion of the sensory flaps with the sides of the pharynx.

In view of such a method of feeding, the idea of a food-catching function on the part of the filaments must be rejected. Moreover, as the mouth of the worm in its burrow is situated some distance beneath the surface and the filaments are waving in the water above, how is any such function practicable ?

I am convinced that it is only under direst necessity that Cirratulus quits its burrow, and then it is certainly not to swim about actively, as M. Bounhiol suggests, but merely to crawl sluggishly on the surface of the mud. If by an accession of clean water the symptoms of asphyxia are removed, the worm will immediately recommence burrowing.

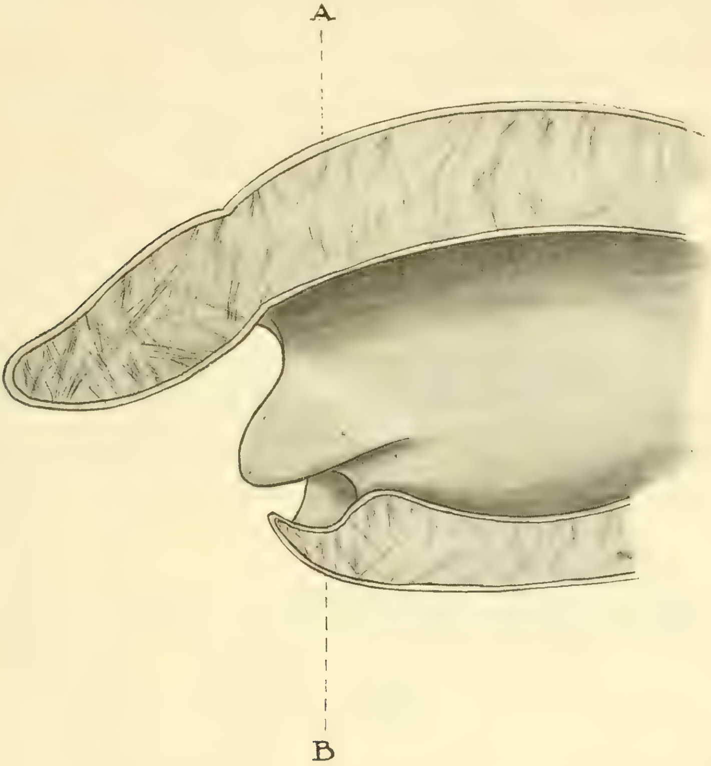


Fig. 7.—Diagrammatic median longitudinal section through the anterior end of Cirratulus.

Nor are the filaments used to collect sand particles. Sand particles adhere to the mucus exuded by the body of the worm, and by so doing probably prevent the walls of the burrow from caving in. They thus allow the animal greater freedom of movement, but there is certainly nothing that can be dignified by the name of a tube.

In conclusion, I wish to thank Mr. F. S. Wright for his able execution of the drawings for half-tone blocks for this paper.

BIBLIOGRAPHY.

1. McIntosh, W. C.—British Marine Annelids. Ray Society, 1915. Vol. III, Part 1, pp. 242 f. Cirratulus tentaculatus.

2. de St. Joseph.—Les Annélides Polychétes des côtes de Dinard. Ann. Sci. Nat. Zoologie, sér. 7, tome 17, 1894, pp. 1 f.

3. Cunningham, J. T., and Ramage.—Polychæta Sedentaria of the Firth of Forth. Trans. Roy. Soc. Edinburgh, 1888, Vol. 33, p. 664.

4. Bounhiol, J.—Respiration dans les Polychæta. Ann. Sci. Nat. Zoologie, sér. 7, tome 16, 1893.

5. Picton, L. J.—The Heart-body and Cœlomic Fluid of certain Polychæta. Quart. Journ. Micro. Sci., 1898–9, Vol. XLI, pp. 263 f.

6. Cunningham, J. T.—Some Points in the Anatomy of Polychæta. Quart. Journ. Micro. Sci., 1887–8, Vol. XXVIII, pp. 239 f.

7. Schaeppi.—Ophelia radiata. Jenaische Zeitschrift, 1894, pp. 247–293.

8. Ashworth, J. H.—Arenicola. Liverpool Mar. Biol. Cttee. Memoirs, 1903.

9. Bohn, Georges.—De l'évolution des connaissances chez les animaux marins littoraux. Bulletin de l'institut general psychologique, 1904, No. 2, Mars-Avril, pp. 190 f.

10. Id.—Observations biologiques sur les Arenicoles. Bull. du Museum d'Histoire Naturelle, 1903, No. 2, pp. 62-73.

11. Id.—Les intoxications marins et la vie fouisseuse. C. R. Ac. Sci. Paris, 1901, tome 133, pp. 593–596.

12. Meyer, Ed.—Studien über den Körperbau der Anneliden. Mitt. Zool. Stat. Neapel, VII, 1887, p. 669, note.

An Account of the Researches on Races of Herrings

Carried out by the Marine Biological Association at Plymouth, 1914–15.

By

J. H. Orton, D.Sc.,

Naturalist at the Plymouth Laboratory.

With Figs. 1 to 6 in the Text.

CONTENTS.

PAGE
Investigations made 72
The characters studied 72
Method of work 74
1st Series of operations : weighing, measuring, recording gonad 75
2nd Series of operations : counting 75
3rd Series of operations : preparing skeletons 75
Distribution of work among the workers 76
Description of the working of the separate samples 77
Sample I 77
Sample II 77
Sample III 78
Sample IV 78
Explanation of Records of Characters 1*a* and 1*b* in Samples II and III . . . 79
Explanation of Records of Characters 13, 14, and 17 in Sample III and Character 17 in Sample II 79
Explanation of Records of Characters 13, 14, and 17 in Sample IV 81
Explanation of Records of Character 18 in Samples II, III, and IV 82
Explanation of Records of Characters 1 to 9, 11, 12, 15, and 16 in Samples III and IV 82
Definition of Character 7 83
Accuracy of measurements 84
Remarks on Additional Characters to those recommended by the Board . . 86
Tables I to IV 87
Appendix to Tables 118

[The following Tables record the measurement and enumeration of a number of characters in certain samples of Herrings taken in the neighbourhood of Plymouth. The work was carried out as part of a general scheme for studying the question of the existence of local races of herrings around the British Coasts, which was organised by the Board of Agriculture and Fisheries. In consequence of the war there is no immediate prospect of the figures being analysed and compared with similar figures relating to fish obtained in other localities. It has therefore been thought advisable to place them on record as they stand, so that they may be available for other workers at any time. The short explanatory statement of the methods employed was prepared by Dr. Orton, who had charge of most of the work, to accompany the figures when they were sent to the Board of Agriculture and Fisheries, and was not written by him with a view to publication. The drawings have been made by Mrs. Sexton.—E. J. ALLEN.]

THE INVESTIGATIONS MADE.

IN accordance with the general scheme of the Board of Agriculture and Fisheries two samples of herrings each of more than 500 specimens have been examined. In the season of 1914–15 we were able to examine in such numbers only the herrings spawning near Plymouth, i.e. in the locality of Bigbury Bay. In December, 1914, a sample of 550 herrings of the shoal spawning in this area was examined in all the characters recommended by the Board, and in January, 1915, a further sample of 525 fish from the same locality was investigated similarly.

In early December, 1914, a small sample of herrings from Cawsand Bay was examined for the purpose of practice and also for comparison with fish from the spawning grounds.

Along with the investigations mentioned above are submitted particulars of a sample of 84 herrings taken in the Channel and examined by Mr. R. S. Clark in July, 1914.

THE CHARACTERS STUDIED.

The following is the scheme of the characters studied, as authorised by the Board of Agriculture and Fisheries :—

All measurements* are to be made with the special apparatus supplied by the Board. The fish should be placed upon the board in such a way that the snout is pressed against the end board sufficiently hard to keep the mouth shut and the body of the fish should be at right angles to the end board. The measurements are to be in all cases the shortest distance from the end board to each point specified. They are to be in the order given below, and tabulated in this order on the forms supplied. A diagram of the herring is appended (Fig. 1), showing the measurements to be taken.

The measurements required are as follows :—

From the end board to

(1) Nearest point of bony orbit.

(2) Hinder edge of operculum.

---

* Measurements are all given in centimetres.

(3) Anterior end of dorsal fin.
(4) Base of pelvic fins.
(5) Posterior end of dorsal fin.
(6) Anterior end of anal fin.
(7) Posterior edge of hindmost scale.*
(8) Distal end of mid-caudal ray.
(9) Distal end of longest ray in dorsal fluke of caudal fin, when fluke is placed so that its dorsal margin lies parallel to line of measurement (i.e. line on board upon which snout and mid-caudal ray should lie).

These measurements made, the following are counted :—

(10) Number of keeled scales on median ventral line in front of base of pelvic fins. [This character was found unreliable and was omitted.]

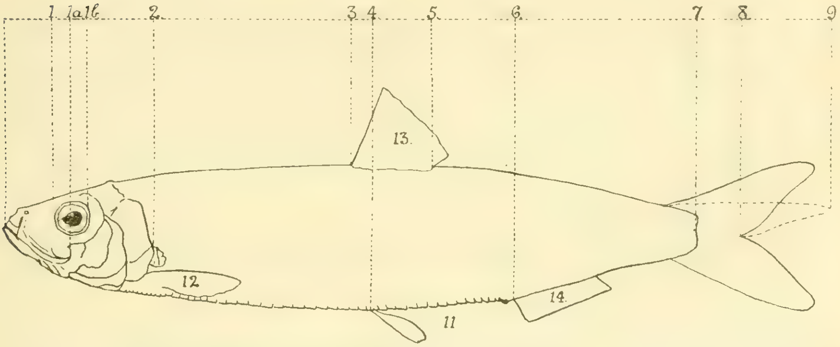


FIG. 1.—Diagram of Herring, showing the measurements, etc., taken by Dr. Orton, copied from the figure supplied by the Board of Agriculture and Fisheries.

(11) Number of keeled scales between base of pelvics and anus.
(12) Number of rays in right pectoral fin.
(13) Number of rays in dorsal fin.
(14) Number of rays in anal fin.

Then take

(15) Weight of fish in apparatus supplied † to nearest 10 grms.

Then

Take scales ‡ from neighbourhood of pectoral fins and preserve in envelopes to be examined by Hjort's method.

Then open fish and take

(16) Sex and degree of maturity (Hjort's scale).

---

* See p. 83.

† Each fish was weighed singly to the nearest gram on an ordinary balance in our work.

‡ The scales were forwarded to the Board for examination. The pyloric cæca of eac fish were also preserved (see p. 86).

State of sexual organs is classified in 7 stages (Publications de Circonstance, No. 53, p. 35).

Stage I. Virgin individuals. Very small sexual organs close under vertebral column. ♀ wine-coloured torpedo-shaped ovaries about 2–3 cm. long and 2–3 mm. thick. Eggs invisible to naked eye. ♂ whitish or greyish-brown knife-shaped testes 2–3 cm. long and 2–3 mm. broad.

Stage II. Maturing virgins or recovering spents. Ovaries somewhat longer than half the length of ventral cavity, about 1 cm. diam. Eggs small but visible to naked eye. Milt whitish, somewhat bloodshot, same size as ovaries, but still thin and knife-shaped.

Stage III. Sexual organs more swollen, occupying about half of ventral cavity.

Stage IV. Ovaries and testes filling two-thirds of ventral cavity. Eggs not transparent. Milt whitish, swollen.

Stage V. Sexual organs filling ventral cavity. Ovaries with some large transparent eggs. Milt white, not yet running.

Stage VI. Roe and milt running (spawning).

Stage VII. Spents. Ovaries slack with residual eggs. Testes baggy, bloodshot.

Doubtful cases are indicated by quoting two stages, e.g. St. I–II, St. VII–II, etc.

Then attach label to fish and count

(17) Serial number of first vertebra having complete hæmal arch.*

(18) Total number of vertebræ.

METHOD OF WORK.

The measurements and weighings of the fish were first made and the counting of the scales and fin-rays accomplished in a second series of operations, and finally the skeletons were prepared in a third stage.

It was found possible to take the weight and measurements of only 250 fish in the first sample and 300 fish in the second sample within 24 hours of the landing of the fish, but weights and measurements of the whole samples of 550 and 525 respectively were completed within less than 36 hours of the landing of the fish. The fish not examined on the first day were kept in an ice chamber until required and remained in good preservation. It may here be noted that both the larger samples were obtained from steam-drifters, on which boats it appears that the fish are subjected to rougher handling than on sailing drifters. Some fish were damaged with respect to one or more of the characters required, and were rejected ; apart from these damaged fish there was no other selection effected.

---

* The figures given in Tables II, III, and IV denote the number of vertebræ with perfect and imperfect hæmal arches. For details see pp. 80–82.

Both larger samples were samples from a large haul of fish and were taken at random from the catch.

The method of work in detail was as follows :—

1st series of operations.

The fish were first weighed singly and a sample of the scales taken from the region under the pectoral fin and put in a previously numbered envelope. A light metal label attached to a small safety pin was then stuck into the fish, which was passed on to be measured, the weight of the fish in the meantime being called out to the recorder. The measurements 1 to 9 were then taken –being called out and recorded successively. The sex and condition of the gonad were next determined and recorded and the fish finally labelled—by pinning the label to the skull through the orbit—and put into an ice-chest tray. Four persons were concerned in this operation —one to weigh and take scales, one to record, one to hand the fish on and assist mechanically with the measuring, and one to measure and take condition of gonad and sex. It was found that weighing and taking scales could be done on the whole rather more quickly than taking measurements and sex. In this way from about 34 to 44 fish could be examined in one hour's continuous work. The time within which a given number of fish were examined was noted and is given in the account of the examination of the different samples.

2nd series of operations : Counting.

In the large samples the counting of the keeled scales and fin rays (Characters 11 to 14) began on the third day of the investigation and was finished on the fourth. When four workers were available each counted the same fin—or the scales—in all the fish, and handed each fish on to his or her neighbour in turn. In the early stages of the work each worker called out the count to be recorded, and later each worker kept a record to check the count called out, but in the whole of the second sample, each worker simply recorded his or her own work. When the Characters 11 to 14 had been recorded the alimentary canal was taken out and labelled with the number of the fish, and preserved for the future examination of the pyloric cæca.

3rd stage : Preparing skeletons.

It was found better to place the fish in cold water, to bring the water to the boil, and allow to boil only two minutes than to boil for ten minutes.

Not more than upwards to about 50 fish were boiled at a time, and a shallow tray which just fits into the fish kettle was used for containing the fish during boiling, one tray being used for boiling while the boiled fish in another tray were being cleaned.

It was found that with one worker cleaning the fish roughly, another worker could clean up to 30 skeletons in an hour after a little practice. The skeletons of the whole sample in each case were prepared in two working days by one worker cleaning them roughly and two others cleaning them finally. All the skeletons have been kept with their own label for future reference and comparison with others. It was found important not to clean the skeletons too well in the region in front of the anterior complete hæmal arches, and to cut the vertebral artery at an early stage in the cleaning operation. The prepared skeletons were kept in shallow wooden trays.

DISTRIBUTION OF WORK AMONG THE WORKERS.

The work in the different stages was accomplished with the help of workers who gave their services at different times. The responsibility for the method and form of the work was undertaken by Dr. Orton, but the assistance rendered by the team of helpers can best be shown in tabular form as follows :—

Weighing and taking scales . . .	Mr. A. J. Smith.
Recording	Miss Clark, Mrs. Matthews, Dr. Allen.
Measuring characters 1 to 9 and recording sex and condition of gonad . .	Dr. Orton.
Counting rays in pectoral fin . . .	Mr. A. J. Smith, Dr. Orton.
Counting rays in dorsal fin . . .	Dr. Allen, Mr. Crawshay, Dr. Orton.
Counting rays in anal fin . . .	Mrs. Orton, Mrs. Matthews, Dr. Allen, Dr. Orton.
Counting keeled scales between pelvic and anal fins	Dr. Orton.
Preparing skeletons	Dr. Orton, Mr. Smith.
Counting vertebræ	Dr. Orton.
Checking counting of vertebræ . .	Mrs. Orton, Mrs. Matthews, Dr. Allen.

Mr. William Searle assisted in handling and labelling the fish and labelled the gut with attached pyloric cæca for further examination.

It may be mentioned that a fair amount of practice in measuring, weighing, recording, and counting was done by Dr. Orton, Mr. Smith, Miss Clark, and Mrs. Orton before the large samples were investigated.

DESCRIPTION OF THE WORKING OF THE SEPARATE SAMPLES.

Four samples of herrings have been investigated fully, two smal samples and two large ones. For the sake of convenience they have been numbered in chronological order.

Sample	I.	84	herrings	9 miles S. of Looe, July 15, 1914.
,,	II.	32	,,	from Cawsand Bay, Dec. 9, 1914.
,,	III.	550	,,	from 6 miles W. by S. of Start Point, Dec. 15, 1914.
..	IV.	525	,,	from about 8 miles W.S.W. to about 3 miles S.S.W. of Start Point, Jan. 6, 1915.

Sample I.

Particulars of this sample are given on the recording sheets. Characters 13 and 14 are given as totals. This sample, being a batch of summer herrings from the Plymouth district, should be specially interesting in comparison with the winter spawning herring; it was examined by Mr. R. S. Clark, with the assistance of Mr. E. Ford and Mr. F. M. Gossen.

Sample II.

This sample of 32 fish from a total catch of from 250 to 300 was taken on December 9, 1914, from drift nets moored in Cawsand Bay. The fish were in excellent condition and were weighed and measured during the morning of December 9.

In this sample two additional characters to those recommended by the Board were investigated, namely, (*a*) the position of the posterior border of the maxilla in relation to the position of the eye, and (*b*) the number of pyloric cæca. The former necessitated two additional measurements, which were numbered "1*a*" and "1*b*." 1*a* is the shortest distance between a line tangent to the posterior border of the maxilla taken at right angles to the long axis of the fish, and a line tangent to the tip of the lower jaw at right angles to the long axis of the fish.

1*b* is the shortest distance between a tangent to the posterior border of the orbit taken at right angles to the long axis of the fish, and a similar tangent to the tip of the lower jaw.

To obtain the number of pyloric cæca the gut of each fish was taken out and preserved with a label attached bearing the same serial number as the fish.

The number of fin rays is given in each case as a total, but during the examination of the fin rays it was observed that an attempt might be made to analyse the fin rays in the dorsal and anal fins. The analysis of the vertebræ in this sample is the same as in the larger Samples III and IV (see pp. 80 and 82).

Sample III.

This was a sample of 550 fish examined from a catch of 22 cran, i.e. about 20,000 herrings. The fish were caught in herring drift nets by the steam-drifter *Diadem*, Lowestoft, near Bigbury Bay, with Start Point bearing about E. by N. 6 miles. The sample was taken at random from the catch, and consisted of fish of various sizes, but mostly in a condition approaching ripeness. Fish which were damaged were not investigated ; otherwise there was no selection.

In the circumstances under which the research was carried out it was possible to examine only 250 fish in measurements, weight and condition of gonad on the first day, that is within 12 hours of the landing of the fish. The fish not examined the first day were kept in ice, and were found to be in excellent preservation on the second day, when the remainder of the sample, namely 300 fish, was examined for measurements, weight and condition of gonad. The whole sample was examined within 35 hours of the landing of the fish, and a record of time was taken as the examination of each lot of 50 fish was completed. These records are given with those for Sample IV in tabular form on page 79.

Sample IV.

In this sample 525 fish out of a catch of 56 cran, i.e. about 50,500 herrings, were examined. The catch was taken by the steam-drifter *G.M.V.* 1062, Lowestoft, in herring drift nets near Bigbury Bay, between a region 8 miles W.S.W. of Start Point and a position about 3 miles S.S.W. of Start Point. The fish were caught during the night of January 5–6, 1915, and landed about 10 a.m., January 6. Work was begun on the sample during the same morning, and 300 fish examined for weight, measurements and condition of gonad in the course of the day. The completion of the examination of the whole sample was effected within 33½ hours of the landing of the fish.

The fish were mostly in a condition almost ready for spawning, some few being spent. In this sample there were a good many damaged fish, and to obtain 525 fish from a sample of 600 it was necessary to reject about 40 to 50 fish, most of which were too badly damaged about the head to be measured. The damage to these specimens had undoubtedly chiefly occurred in unmeshing them. No selection of specimens occurred other than that of damaged ones.

The times at which successive batches were examined for weight, measurements and condition of gonad are shown with those for Sample III in the following table :—

Total fish examined.	Sample III.	Hours from landing.	Sample IV.	Hours from landing.
		Hr. min.		Hr. min.
50	12.40 P.M. Dec. 15	2.10	12. 2 P.M. Jan. 6	2. 2
100	4.30 ,, ,,	6. 0	2.58 ,, ,,	4.58
150	7.30 ,, ,,	9. 0	4.40 ,, ,,	6.40
200	8.55 ,, ,,	10.25	7.20 ,, ,,	9.20
250	10.13 ,, ,,	11.43	8.47 ,, ,,	10.47
300	11.55 A.M. Dec. 16	25.25	10. 4 ,, ,,	12. 4
350	1. 5 P.M. ,,	26.35	11.49 A.M. Jan. 7	25.49
400	4.35 ,, ,,	30. 5	2.45 P.M. ,,	28.45
450	7.20 ,, ,,	32.50	4.30 ,, ,,	30.30
500	8.30 ,, ,,	34. 0	7. 0 ,, ,,	33. 0
550 or 525	9.40 ,, ,,	35.10	7.35 ,, ,,	33.35

EXPLANATION OF RECORDS OF CHARACTERS 1A AND 1B IN SAMPLES II AND III.

In Sample III two characters in addition to those recommended by the Board were examined in a few fish. These characters are 1*a* and 1*b*. Character 1*a*, as in Sample II, is the shortest distance between a tangent to the posterior border of the maxilla taken at right angles to the long axis of the fish, and a tangent to the tip of the lower jaw at right angles to the long axis of the fish. Character 1*b* is the shortest distance between a tangent to the posterior border of the orbit taken at right angles to the long axis of the fish, and a similar tangent to the tip of the lower jaw.

It was found, however, that the taking of those measurements would decrease the number of fish examined within the shortest time recommended for the Characters 1 to 9, hence it was decided at an early stage to discontinue to take the additional ones.

EXPLANATION OF RECORDS OF CHARACTERS 13, 14, AND 17 IN SAMPLE III.

With regard to Characters 13, 14 and 17 on the sheets an attempt has been made in the case of the fins (13 and 14) to analyse them, and in the case of the vertebræ with hæmal arches to give additional information. The records for these characters are given in the general form of $a+b$.

In Sample III the dorsal and anal fins (13 and 14) were analysed in the following manner : in each case the fin-rays in the anterior portion of the fin equal to or less than two-thirds the height of the longest rays were counted separately from the fin-rays posterior to them; thus the records take the form of $a+b$, the sum of which gives the total number of rays in the fin. A cursory examination of the records indicates that 2+17 is the commonest form for the dorsal fin and 2+15 the commonest form for the anal fin (Figs. 4 and 5).

In the case of Character 17, which is stated in the scheme to be the "serial number of first vertebra having complete hæmal arch," the records have been made in the form of $(a+b)$ where $b=$ the total number of vertebræ with complete hæmal arch—not, however, counting the terminal vertebra-like ossicle regarded by Williamson as the "last vertebra" (see Fisheries, Scotland, Sci. Invest., 1914, I (April, 1914) Fig. 7, B, p. 21). Williamson's figure is here reproduced as Fig. 2.

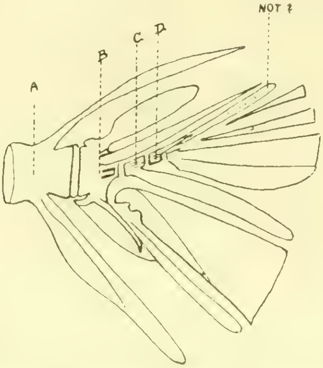


Fig. 2.—Diagram of Tail-bones of Herring, from Williamson. A is the last vertebra counted in the present work. B is regarded by Williamson as the last vertebra. Not ? = Notochord ?

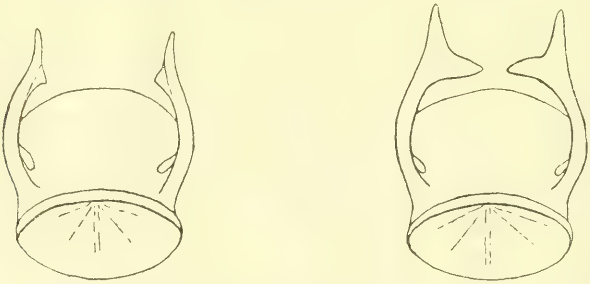


Fig. 3.—Vertebræ, showing incomplete but "well-developed" hæmal arch.

In this character (17), $a=$ the number of vertebræ having an incomplete, but "well-developed" arch, and an arch was considered "well developed" if the hæmal processes were almost as large as those of the first complete arch, and if these processes possessed even the smallest trace of an internal cross-piece (see Figure 3). It should be mentioned that all intermediate stages are met with between a trace of an internal cross-piece and a complete arch. It is not improbable that in the living animal these arches are closed by a cartilaginous cross-piece. Cursory examination of the records indicates that in a majority of skeletons the sum of the number of vertebræ with complete hæmal arch and the number with well-developed (i.e. potentially complete ?) arches is 33 ; or it might be said that the commonest number of vertebræ with potentialities for complete hæmal arches is 33 ; the greatest number of such vertebræ appears to be 35.

EXPLANATION OF CHARACTERS 13, 14, AND 17 IN SAMPLE IV.

In Number IV Sample it was thought that more information could be obtained by analysing the dorsal and anal fin (Characters 13 and 14) in a slightly different way from that adopted in Sample III.

Thus in Sample IV all the anterior fin-rays of the dorsal fin which were distinctly shorter than the longest fin-ray were counted separately from the following and recorded in the general form of $a+b$, where a is the number of the smaller anterior rays and b the number of rays posterior to these. In this way it is possible to reconstruct a fin to represent the commonest form which by cursory examination of the records is seen to be one having 3+16 rays. A drawing of the type of ray is shown in Fig. 4.

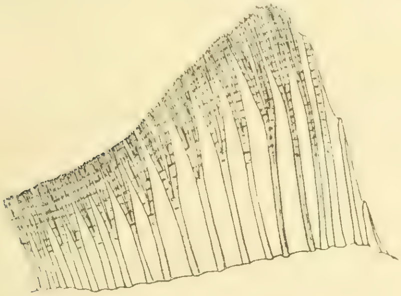


FIG. 4.—Dorsal Fin. In Sample III the above would be recorded as 2+17 ; in Sample IV as 3+16.

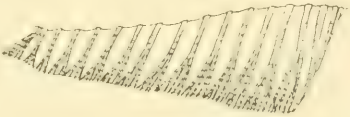


FIG. 5.—Anal Fin. In Sample III the above would be recorded as 2+15 ; in Sample IV as 3+14.

In the case of the anal fin (Character 14) the fin was analysed in the following manner : all the anterior fin-rays which were not subdivided at the tip or splayed out in any way were counted and recorded separately as "*a*" from those in which the rays were splayed out—recorded as "*b*." The commonest form of fin is seen from the records to be one recorded as 3+14. This type of fin is shown in Fig. 5.

Character 17 in Sample IV is also recorded in a manner slightly different from that in Sample III. In this sample (IV) it was decided to include under " well-developed " open hæmal arches those in which the hæmal processes were relatively stout to those of the first closed arch, but which processes did not necessarily possess the trace of a cross-piece on their internal faces. This change of recording has resulted in only a slight difference in the records, but in a few cases the number of vertebræ recorded in the " *a* " category is higher than in corresponding skeletons in Sample III.

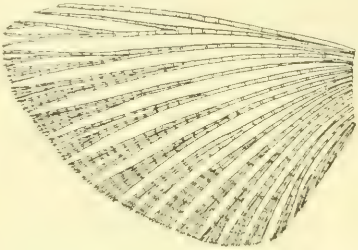


FIG. 6.—Pectoral Fin. 17 rays.

It should be mentioned that in some skeletons the hæmal processes of the vertebræ anterior to the first vertebra with complete arch were missing, having been cleaned away; in these cases the following mark † is placed alongside the record.

EXPLANATION OF THE RECORDS OF CHARACTER 18 IN SAMPLES II, III, AND IV.

The number of vertebræ given in column 18 is the number of vertebræ between the skull and the ossicle marked B in Fig. 2. It may be reiterated that the ossicle marked B in the figure is *not* included in the total given. Remarks on abnormalities or noteworthy features of particular skeletons are connected by an asterisk to explanations in the Appendix to the Tables. It may be noted that in several skeletons two or more vertebræ have apparently become fused together; as, however, such fused vertebræ show uniformly only two articulations, they have in each case been counted as one vertebra, although it is most probable that most of these abnormal vertebræ are equivalent to two or more normal ones. Each case is discussed in the Appendix to the Tables.

EXPLANATION OF RECORDS OF CHARACTERS 1 TO 9, 11, 12, 15, AND 16 IN SAMPLES III AND IV.

Characters 11 and 12 call for little comment.

In counting the keeled scales between the pelvic fin and anus (11) the adjacent scales were cleaned well away before beginning to count. In this way the insertions of the keeled scales could be made out and their total number established with certainty. Practically no difficulty was experienced in counting the rays in the pectoral fin (12). It was noticed, however, that in fins with a large number of rays the increase in the number appeared to be accounted for by additions of small rays near the posterior border. No attempt was made to analyse this fin as in the case of the dorsal and anal fins, but it is possible that useful information might be obtained by attempting such an analysis.

The weight of the fish (15) was taken separately and to the nearest gram.

In recording the condition of the gonad (16) it was found necessary to use combinations of the numerals representing different stages, which require explaining.

In the records occur such combinations as IV–VI and VI–IV. A record such as IV–VI is put down to represent fish in which the gonad appeared to be about ripe, although it did not fill the body cavity entirely. These records, however, refer mostly to males, in which the approach to and incidence of ripeness of the gonad are not easy to differentiate. In the case of records such as VI–III or VI–IV, these indicate that the gonad is definitely ripe, but has become reduced by spawning (or compression in some cases) to the size in the stage indicated by the second numeral; thus VI–IV indicates gonad reduced to the size of half the volume of the abdominal cavity. The numeral VII was reserved for fish which were spent or practically spent. By distinguishing spawning fish in this way it is possible to correlate to some extent the weight with the size of the fish.

With regard to Characters 1 to 9 all measurements were taken with the instrument supplied by the Board of Agriculture and Fisheries. An attempt was made to measure Character 1 to the nearest ·2 of a millimetre in Samples III and IV.

Character 2 was measured to the nearest ·5 mm. in Sample III and to ·2 mm. in Sample IV.

Characters 3 to 9 were measured to the nearest ·5 mm. in both Samples III and IV.

DEFINITION OF CHARACTER 7.

Characters 1 to 9 are those recommended by the Board except No. 7. Character 7 is defined in the Scheme as " from the end-board, etc. . . . to the posterior edge of the hindmost scale." In preliminary investigations, however, it was found that posterior scales were either rubbed loose or missing in about one-third of the specimens examined. It was therefore decided to use some other fixed point of more constant position. The point chosen is in all probability the one shown in the figure of the Herring supplied by the Board. It is the point from which the perpendicular 7 arises, and marks the origin of the median caudal rays from the muscular part of the tail. The muscular part of the tail is covered by an epidermis of metallic appearance, and is in nearly all cases sharply marked off from what may be regarded as the tail fin proper where this kind of epidermis is absent. The caudal fin-rays are slightly embedded in the fleshy part of the tail. Thus the point chosen for measurement may be stated shortly to be the *origin of the mid-caudal rays from the fleshy part of the tail.*

The origin of these rays is, however, a concave line, as indeed is shown in the Board's figure, and the point actually measured is the line at right angles to the long axis of the fish which forms a tangent to the posterior border of the fleshy part of the tail. This line is apparently the same as the perpendicular No. 7 shown in the Board's figure.

There were only a few fish in which this point was at all difficult to determine and these were among Sample IV. It is of course well known that the posterior scales extend over the mid-caudal fin-rays.

ACCURACY OF MEASUREMENTS.

Before the large samples were examined a batch of 33 fish was examined twice, in order to obtain some determination of the error in measuring under the conditions in which the samples would be examined. The fish measured were not in good condition, so that it is probable that the errors observed in this case would be the maximum error, especially as more practice in measuring was obtained afterwards. In this experiment the average difference in the two sets of readings was less than 1 mm. in all measurements except 4 and 6, in which the average difference was 1·3 mm. and 1·1 mm. respectively. These 33 fish were examined in 47 and 45 minutes respectively, i.e. about the rate of 44 per hour, about the maximum rate for the large samples. After this experiment assistance was obtained in making measurements for Characters 3, 4, 5, and 6, and there can be no doubt that the accuracy of the measurements was thereby increased. In all measurements therefore it may be confidently stated that they are correct on the average to one millimetre, and in the case of 1 the average error is probably not more than ·5 mm. It is believed that only isolated *errors of measurement* occur of as much as 3 mm., but errors would increase in frequency towards zero.

It is, however, possible that occasional *errors of observation* may occur of as much as 5 mm. where the ·5 cm. line on the scale has been read as a whole cm. division line, for one or two cases of this kind were actually observed in time to prevent this error. It is probably very difficult to exclude completely *occasional* lapses of this nature in examining large numbers of fish at the high rate of speed required.

It is unfortunate in some respects that the experimental sample mentioned above was not a fresh sample exactly comparable with a research sample, and it would probably be better in future work to re-examine a batch of the research sample in order to determine the error of measurement.

An experiment was carried out to determine how accurately the instrument would measure. A number of slips of paper (30) were ruled with lines parallel to one end, which was placed against and was parallel with the "end-board" of the instrument. The points measured on the ruled lines were similar to those measured on herrings, so that in measuring them it was necessary to move the instrument about in approximately the same way as when measuring the research herrings. The slips of paper represented in fact paper herrings. These 30 slips were measured twice at a rate greater than the maximum rate at which the research samples of herrings were examined. Characters 1 and 2 were read to ·2 mm., and Characters 3 to 9 to the nearest ·5 mm., just as in the research sample. The average difference between the first and second measurements of Characters 1 and 2 was less than ·1 mm., and in only 4 cases was the difference as much as ·3 mm. The average difference between all the measurements of Characters 1 and 2 and the actual distance—as measured by a 15-cm. ivory rule divided to fifths of a millimetre—was also less than ·1 mm., and in only 5 cases were there differences of ·3 mm.

The average difference between first and second measurements of Characters 3 to 9 was less than ·1 mm., and in only one case was the difference more than ·5 mm. The difference was exactly ·5 mm. in 30 cases, and in 159 pairs of measurements the results were exactly the same. In all the measurements of Characters 3 to 9 the average difference from the actual distance measured was about ·13 mm.

In a large number of measurements, however, it is considered that the instrument may be taken as reading accurately *on the average*, since the plus and minus variations would tend to balance each other, although ranging between plus and minus the maximum error mentioned above. The average algebraical error of all the measurements taken in the paper-herring sample mentioned above was less than +·03 mm. in Characters 1 and 2, and +·04 mm. in Characters 3 to 9.

REMARKS ON ADDITIONAL CHARACTERS TO THOSE RECOMMENDED BY THE BOARD.

In Sample II two additional characters to those recommended by the Board were examined, namely, the relation of the posterior border of the maxilla to the orbit, and the number of pyloric cæca. In the large sample it was found impracticable to examine the former character in addition to the Board's characters, owing to the exigencies of time, but the pyloric cæca of all the fish in Samples III and IV have been preserved with their proper number, and can be examined and recorded at leisure.

The examination of these characters is considered of equal importance to those recommended by the Board, since they are characters in which *Clupea harengus* differs from allied species.

HAUL.

Table I. Herring Race Investigations.

SAMPLE I.

Position . . 9 miles S. of Looe; Plymouth.
Date . . July 15/14. (Nets shot July 14/14.)
Vessel . . Motor Drifter (Looe Boat) "John Wesley."
Net . . Drift net.

Number examined . . 84.
Quantity of fish caught . 1000 (total catch).
Date examined . . July 15/14.
Examined by . . R. S. Clark.

The characters are briefly: Length in centimetres from snout to **(1)** eye, **(2)** operculum edge, **(3)** front of dorsal fin, **(4)** pelvic, **(5)** back of dorsal, **(6)** front of anal, **(7)** root of tail, **(8)** end of mid-caudal, **(9)** end of longest caudal ray. Number of **(11)** keeled scales (pelvics to anus), **(12)** rays in pectoral, **(13)** rays in dorsal, **(14)** rays in anal, **(15)** weight in grams, **(16)** sex and maturity.

No. of fish.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**	**16**
1	1·3	4·2	10·2	10·5	12·5	14·8	19·7	20·3	22·6	15	16	19	19	107	♀ i
2	1·4	4·4	10·9	11·1	13·2	15·8	20·9	21·7	24	14	16	18	18	123	♂ i–ii
3	1·3	4·1	10	10·4	12·6	15	19·7	20·5	22·5	14	17	19	18	104	♀ i
4	1·2	3·7	9·6	10·1	11·8	14·9	19·4	20·3	22·3	15	18 ?	18	17	91	♀ i
5	1·3	4·3	10·1	10·6	12·6	15·1	20·3	21·1	23·3	15	16	20	17	129	♀ i–ii
6	1·4	4·5	11·6	12·2	14·3	17·3	22·7	23·8	26·1	15	16	20	18	151	♀ i
7	1·3	4·2	10·3	10·4	12·7	15·5	20·3	21·3	23·6	14	17	19	16	120	♀ i
8	1·3	4·3	11·1	11·6	13·9	16·7	22	22·8	25·2	15	17	19	17	146	♀ i
9	1·3	4·2	10·4	11	12·8	15·6	20·1	21·3	23·5	15	17	20	18	112	♀ i
10	1·2	4	9·8	10·4	12·3	14·5	19·6	20·3	22·3	14	16	19	17	100	♂ i
11	1·3	4	10·3	10·9	12·8	15·4	20·4	21·4	23·5	15	16	19	18	118	♂ i
12	1·2	4·3	10·6	11·2	13·2	15·8	20·8	21·8	24·2	15	17	19	18	121	♀ i
13	1·2	4	10·3	10·5	12·8	15·4	20	21	23·1	15	16	19	18	112	♀ i
14	1·2	4	10·1	10·3	12·4	15·0	19·6	20·2	22·2	15	15	19	17	101	♂ i–ii
15	1·2	4·1	10·3	10·6	12·7	15·1	20·1	20·7	23·1	15	16	19	17	116	♀ i–ii
16	1·2	4·1	10·1	10·8	12·9	15·3	20·2	21·2	23·5	14	15	19	19	122	♀ i
17	1·2	3·9	9·7	9·9	12	14·5	18·8	19·6	21·6	15	17	19	18	82	♀ i
18	1·3	4·3	10·5	10·8	13·4	15·5	20·9	21·6	24·1	15	17	19	18	126	♂ i–ii
19	1·3	4·2	10·5	11	12·9	16·1	21	21·8	24·1	15	17	18	18	126	♀ i–ii
20	1·2	3·9	9·4	10·1	11·9	14·5	18·8	19·8	22	15	16	19	18	90	♀ i
21	1·3	4·2	10·1	10·7	12·6	15	19·8	20·8	23·1	14	17	19	19	118	♀ i–ii
22	1·3	4·1	10·2	10·7	12·7	15·3	20	20·7	23	16	17	20	17	100	♀ i
23	1·3	4·5	11·1	11·6	13·7	16·7	21·5	22·6	25·1	15	16	19	19	138	♀ i–ii
24	1·2	4	9·9	10·3	12·3	14·9	19·7	20·4	22·7	14	17	19	18	111	♀ i
25	1·2	4·2	9·8	10·7	12·5	15·1	20·1	21	22·3	14	17	19	18	114	♂ i
26	1·2	3·8	10	10·6	12·3	15	19·8	20·8	22·6	15	15	17	16	102	♂ i
27	1·2	4·2	10·2	10·8	12·8	15·9	20·6	21·5	23·8	14	16	19	17	128	♀ i–ii
28	1·3	4·3	10·3	11	12·7	15·4	20	21·0	23·3	14	16	18	16	121	♀ i
29	1·2	4·1	9·8	10·5	12·4	15	19·9	20·6	22·7	15	17	18	18	107	♀ i–ii
30	1·2	4·1	10	10·3	12·4	15	19·7	20·7	23	15	16	19	17	100	♀ i–ii
31	1·2	4·2	10·1	10·6	12·7	15·1	19·9	20·7	22·8	14	17	19	18	114	♀ i–ii
32	1·1	4	9·6	10·4	12·2	14·3	19·3	20	22·2	15	17	19	18	114	♂ i
33	1·1	4	10·1	10·3	12·4	14·7	19·4	20·1	22·4	14	17	19	19	105	♂ i
34	1·2	4·1	10·1	10·8	12·6	15·1	20·2	20·9	23·1	15	17	19	18	113	♂ i–ii
35	1·2	4·2	10·3	10·7	12·7	15·2	20·2	21·1	23·3						
36	1·2	4	9·3	10	11·9	14·1	18·7	19·4	21·7	15	17	19	18	92	♀ i–ii
37	1·2	4	9·8	10·6	12·6	15·1	19·7	20·6	22·9	15	16	19	17	114	♂ i–ii

No. of fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16
38	1·2	4·3	11·3	11·9	14·1	17·3	22·2	23·1	25·4	16	17	19	18	154	♂ ii
39	1·3	4·3	10·8	11·6	13·6	16·5	21·9	22·7	25·1	15	18	20	17	140	♂ i–ii
40	1·2	4·1	10	10·7	12·5	15	19·9	20·7	22·8	14	15	20	18	112	♀ i
41	1·2	4·2	10·1	10·6	12·8	15·1	20·2	21	23·3	14	17	19	19	113	♀ i–ii
42	1·2	4·3	9·9	10·6	12·4	15·2	20·2	21	23·1	14	17	19	16 ?	115	♂ i
43	1·2	4·3	10·1	10·7	12·9	15·4	20·7	21·5	23·8	14	17	19	17	122	♂ i
44	1·2	4·2	9·8	10·3	12·3	13·8	19·2	20·2	22·2	15	17	19	17	93	♀ i
45	1·2	4·2	9·9	10·5	12·4	15·1	19·4	20·3	22·4	14	18	19	18	104	♀ i
46	1·3	4·3	10	10·6	12·7	15·3	20	21	23·3	15	19	19	19	113	♂ i
47	1·2	4·2	10·3	10·7	12·8	15	20·1	21·1	23·4	15	17	19	19 ?	118	♀ i
48	1·3	4·5	10·8	11·3	13·5	16·3	21·5	22·3	24·9	14	17	20	17	155	♂ ii
49	1·3	4·4	10·4	11·2	13	15·5	20·7	21·5	23·8	14	17	19	16	127	♂ i–ii
50	1·2	4·3	10·7	11·3	13·5	15·8	21·3	22·1	24·4	15	17	19	18	130	♀ i
51	1·2	4·4	10·4	10·9	13·0	15·3	20·5	21·1	23·6	14	18	19	17	126	♀ i–ii
52	1·2	4·1	9·7	10·4	12·3	15·2	19·9	20·6	22·9	15	17	20	18	109	♂ i
53	1·2	4·3	10·4	11·3	12·9	16·2	20·6	21·6	24·0	14	16	19	16	117	♂ i ii
54	1·2	4·2	10·5	11·3	13·2	15·5	20·5	21·2	23·5	14	17	19	16	121	♂ i
55	1·2	4·4	10·2	10·9	12·5	15·2	20·2	21	23·2	15	17	20	17	116	♂ i
56	1·2	4·1	9·7	10·4	12·1	14·8	19·6	20·3	22·4	14	17	19	17	105	♂ i
57	1·3	4·4	10·7	11·4	13·3	16·2	21·4	22·1	24·5	15	17	18	18	138	♂ i
58	1·3	4·6	11·4	11·8	14·1	16·8	21·9	22·7	25·3	15	17	19	17	154	♀ i ii
59	1·2	4·1	9·5	10·6	12	14·5	19·3	20·2	22·3	15	17	20	19	108	♀ i–ii
60	1·3	4·4	10·6	11·2	13·4	16	21·5	22·3	24·7	14	17	19	18	141	♀ i–ii
61	1·1	4·1	9·5	10·2	12·1	14·4	19·3	20	22·2	15	17	20	17	102	♂ i–ii
62	1·2	4	9·9	10·5	12·3	15	19·6	20·5	22·7	15	16	19	19	100	♂ i
63	1·2	4	10	10·5	12·2	15·3	19·9	20·6	22·7	14	15	19	17	115	♀ i–ii
64	1·2	4·1	9·7	10·6	12·2	15·1	19·7	20·4	22·6	16	16	18	16	113	♂ i
65	1·2	4·3	9·5	10·1	12	14·4	19·3	20	22·1	14	16	20	18	99	♂ i–ii
66	1·2	4	10·3	11·1	13	15·8	20·6	21·4	23·7	15	17	20	18	113	♀ i
67	1·2	4·1	9·6	10·0	12	14	18·9	19·7	21·8	13	17	18	18	99	♀ i
68	1·2	4·2	9·9	10·6	12·5	15	19·6	20·5	22·8	14	17	19	17	109	♀ i
69	1·1	4·1	9·3	9·9	11·8	14	18·8	19·4	21·5	15	15	19	18	85	♂ i
70	1·1	4	9·5	10·1	12·2	14·4	19·3	19·9	22·2	14	15	20	17	99	♂ i
71	1·3	4·3	10·1	10·9	12·6	15·2	20·2	21	23·3	14	16	19	18	119	♀ i
72	1·2	3·9	9·5	10·2	11·8	14·5	19·1	19·9	21·9	15	17	19	17	98	♂ i–ii
73	1·1	4·1	9·7	10·5	12·1	14·5	19·4	20	22·2	15	16	18	16	101	♂ i
74	1·3	4·5	10·5	11·4	13·3	16·1	21·2	22	24·3	15	17	19	17	137	♂ i–ii
75	1·2	4·1	9·8	10·1	12·2	14·7	19·7	20·3	22·8	15	17	19	18	103	♂ i
76	1·2	4·2	9·7	10·7	12·3	14·7	19·5	20·3	22·3	14	16	20	18	98	♂ i
77	1·1	3·9	9·4	10·2	11·9	14·2	19·1	19·7	21·9	14	16	19	18	91	♂ i–ii
78	1·2	3·9	9·9	10·3	12·3	14·5	19·5	20·2	22·4	14	16	18	18	102	♂ i–ii
79	1·2	4·2	10·2	11·1	13	15·4	20·4	21·2	23·5	14	16	19	18	125	♂ i–ii
80	1·2	4·1	10·2	10·6	12·8	15·4	20·2	21	23·4	15	17	19	17	113	♀ i–ii
81	1·2	4·1	10·0	10·6	12·7	15·2	20·3	20·9	23·3	15	16	19	17	123	♀ i–ii
82	1·2	3·9	9·9	10·5	12·3	15·1	20·2	20·9	23	15	16 + 1	19	18	110	♀ i
83	1·2	4·1	9·8	10·6	12·3	14·7	19·7	20·3	22·7	15	16	19	17	113	♂ i
84	1·2	4·3	10·4	11·3	12·9	15·5	20·4	21·3	23·8	15	17	20	18	119	♂ i–ii

Table II. Herring Race Investigations.

HAUL.

Position	. .	Cawsand Bay (condition of fish : very good).
Date	. .	Early morning Dec. 9/14. Landed morning of Dec. 9/14.
Vessel	. .	Not known.
Net .	. .	Moored drift nets.

SAMPLE II.

Number examined	. .	32.
Quantity of fish caught	.	250–300.
Date examined	. .	Dec. 9/14.
Examined by	. . .	J. H. Orton.

The characters are briefly : Length in centimetres from snout to (**1**) eye, (**2**) operculum edge, (**3**) front of dorsal fin, (**4**) pelvic, (**5**) back of dorsal, (**6**) front of anal, (**7**) root of tail, (**8**) end of mid-caudal, (**9**) end of longest caudal ray. Number of (**11**) keeled scales (pelvics to anus), (**12**) rays in pectoral, (**13**) rays in dorsal, (**14**) rays in anal, (**15**) weight in grams, (**16**) sex and maturity, (**17**) vertebræ with hæmal arch, (**18**) total vertebræ.

No. of fish.	**1**	**1*a***	**1*b***	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	Pyloric cæca.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	No. of fish.
1	1·28	1·86	2·3	4·1	9·8	10·35	12·1	14·5	19·05	20·1	22·3	22	15	17	18	17	79	♂ iv–vi	0+32	55	1
2	1·53	2·1	2·6	4·55	11·45	11·85	14·25	17·15	22·4	23·4	26·25	18	16	17	18	18	149	♂ iv–v	1+31	55	2
3	1·5	1·9	2·55	4·4	10·2	10·65	12·7	15·1	19·8	20·9	23·25	25	15	18	18	17	94	♂ v–vi	0+32	55	3
4	1·6	2·3	2·7	4·95	11·45	12·3	14·2	17·05	22·5	23·65	26·35	20	15	17	18	17	114	♂ ii	1+32	55	4
5	1·4	1·9	2·4	4·45	11·3	11·8	13·9	16·8	21·65	22·7	25·45	17	15	16	19	16	123	♂ iv–v	0+32	55	5
6	1·53	2·0	2·6	4·6	11·15	11·7	13·55	16·5	21·4	22·4	25·1	20	16	17	18	16	106	♂ v	2+31	56	6
7	1·45	2·15	2·6	4·7	11·3	11·8	13·9	16·5	21·9	23·0	25·6	19	14	17	18	18	126	♂ iv–v	1+32	55	7
8	1·33	1·46	2·34	4·2	10·1	10·8	12·55	15·1	19·7	20·8	23·1	18	15	17	19	14	96	♂ v–vi	1+32	56	8
9	1·46	2·0	2·53	4·35	9·95	10·5	12·4	14·45	19·35	20·35	22.85	19	14	17	19	17	91	♂ v–vi	0+32	55	9
10	1·2	1·74	2·2	4·1	10·1	10·8	12·2	15·2	19·75	20·8	22.96	23	15	17	17	15	93	♂ v–vi	2+31	55	10
11	1·4	1·95	2·5	4·4	10·65	11·26	13·2	16·05	21·15	22·15	24·65	20	15	17	20	19	114	♂ iv–v	1+32	56	11
12	1·46	2·15	2·6	4·8	11·5	12·4	14·1	17·3	22·3	23·4	26·1	23	15	16	20	16	106	♂ ii	1+32	56	12
13	1·28	1·73	2·28	4·13	9·65	10·26	12·2	14·25	19·05	20·0	22·4	18	15	18	21	17	83	♂ iii–iv	1+33	57	13
14	1·4	2·0	2·5	4·4	10·1	11·1	12·9	15·2	19·85	20·9	23·4	18	14	18	19	16	100	♂ v	1+32	56	14
15	1·25	1·75	2·25	4·05	9·6	10·3	11·05	14·0	18·55	19·4	?	21	14	16	20	17	78	♂ v–vi	1+31	55	15
16	1·8	2·45	3·1	5·45	12·25	13·15	15·2	18·45	23·95	25·3	28·2	21	15	17	19	17	125	♂ ii	1+33	55	16
17	1·45	2·0	2·5	4·5	10·3	11·45	12·85	15·8	20·7	21·7	24·4	20	15	16	18	1+16	106	♂ v–vi	1+32	55	17
18	1·53	2·05	2·6	4·7	11·0	11·7	13·85	16·05	21·5	22·6	25·2	20	14	17	20	17	114	♂ ii	1+32	56	18
19	1·35	1·77	2·35	4·15	10·3	10·95	12·9	15·85	20·6	21·7	24·25	22	15	16	20	1+17	101	♂ iv–v	1+33	56	19
20	1·5	2·15	2·63	4·8	11·15	11·7	13·8	16·85	21·8	22·95	25·55	19	15	17	19	1+16	119	♂ iii	1+32	55	20
21	1·45	2·0	2·5	4·4	10·95	11·65	13·3	16·2	21·35	22·5	25·0	22	14	16	18	1+16	111	♂ v–vi	1+32	56	21
22	1·42	1·92	2·46	4·3	10·45	11·4	12·8	15·95	20·65	21·65	24·2	20	15	17	18	15	107	♂ iv–v	1+32	56	22
23	1·35	1·9	2·36	4·1	9·3	10·1	11·8	14·2	18·65	19·6	21·9	18	15	17	18	16	78	ii–iii	0+33	56	23
24	1·4	2·0	2·4	4·5	10·7	11·6	13·15	16·2	21·4	22·5	24·95	16	14	17	18	1+16	108	♂ iv–vi	1+33	56	24
25	1·46	2·0	2·45	4·4	10·5	11·1	12·8	15·5	20·5	21·5	24·0	19	15	17	19	1+16	106	♂ v	2+31	56	25
26	1·4	2·0	2·45	4·4	10·05	11·1	12·6	15·3	20·3	21·45	23·8	21	16	16	19	17	103	♂ iv–vi	2+31*	56	26
27	1·3	1·8	2·3	4·3	10·46	11·25	12·8	15·7	20·5	21·4	24·0	21	14	16	19	1+16	81	♂ i–ii	2+31	55	27
28	1·23	1·75	2·2	4·0	9·7	10·55	12·0	14·4	18·85	19·85	22·05	21	14	17	19	2+14	84	iii–iv	2+31	55	28
29	1·5	1·8	2·55	4·4	10·2	10·9	12·75	15·2	19·95	21·1	23·3	22	14	16	18	1+14	94	♂ v	1+32	56	29
30	1·48	2·0	2·53	4·5	10·2	10·25	12·5	15·5	20·1	21·1	23·5	19	15	17	19	1+14	88	♂ v	1+31	55	30
31	1·4	1·88	2·35	4·2	9·5	10·3	11·85	14·3	18·9	19·9	22·3	25	15	17	19	2+14	72	♀ iii	1+32	55	31
32	1·4	2·05	2·45	4·58	11·3	11·7	14·2	16·7	21·85	23·0	25·5	25	16	17	19	2+15	126	♂ iv–v	0+33	56	32

* One vertebra with 2 neural and 2 ventral arches.

Table III. Herring Race Investigations.

HAUL.

Position . . Start Pt. E. by N. 6 miles.
Date . . Dec. 15/14. Landed at 10.30 a.m.
Vessel . . Steam Drifter " Diadem," Lowestoft.
Net . . Drift.

SAMPLE III.

Number examined . . 550.
Quantity of fish caught . 22 crans (about 20,000).
Date examined . . Dec. 15/14.
Examined by . . . J. H. Orton.

The characters are briefly: Length in centimetres from snout to **(1)** eye, **(2)** operculum edge, **(3)** front of dorsal fin, **(4)** pelvic, **(5)** back of dorsal, **(6)** front of anal, **(7)** root of tail, **(8)** end of mid-caudal, **(9)** end of longest caudal ray. Number of **(11)** keeled scales (pelvics to anus), **(12)** rays in pectoral, **(13)** rays in dorsal, **(14)** rays in anal. **(15)** weight in grams. **(16)** sex and maturity, **(17)** vertebræ with hæmal arch, **(18)** total vertebræ. * For explanation of signs see Appendix to Tables.

No. of fish.	1	1*a*	1*b*	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
1	1·5	2·1	2·6	4·8	12·35	13·1	15·55	18·16	23·9	25·2	27·95	15	18	3+17	3+15	156	♂ v	1+32	56
2	1·63	2·36	2·9	5·2	12·45	12·8	15·45	18·2	23·3	24·55	27·6	15	18	3+17	2+15	182	♀ iv–v	0+33	56
3	1·7	2·45	3·05	5·35	12·55	13·65	15·55	18·6	24·4	25·75	28·65	15	16	3+16	2+16	181	♂ v	0+32*	56
4	1·4	2·0	2·5	4·7	11·6	12·55	14·15	17·8	22·85	23·9	26·7	16	16	2+17	2+15	132	♂ iv–v	1+32	56
5	1·47	1·95	2·53	4·6	11·25	12·1	14·0	16·9	22·1	23·3	26·1	14	16	2+17	2+15	141	♂ iv	1+33	56
6	1·8	2·34	3·0	5·25	12·75	13·9	15·8	19·1	24·75	26·0	29·0	14	17	2+17	2+15	205	♀ iv	2+31	56
7	1·5	2·0	2·6	4·6	11·4	12·1	14·0	16·9	21·9	23·1	25·8	14	16	2+17	2+17	156	♂ v	1+32	56
8	1·55	2·2	2·75	5·0	12·0	13·0	14·9	18·1	23·4	24·5	27·4	15	17	2+17	2+16	178	♀ v	2+32	56
9	1·6	2·1	2·75	4·7	11·65	12·6	14·7	18·15	23·0	24·15	27·1	15	16	3+17	2+16	166	♀ iv–v	0+32*	56
10	1·6	2·1	2.78	5·0	11·9	12·85	14·85	18·15	23·25	24·45	27·3	14	18	2+17	2+16	162	♂ iv–v	1+32	55
11	1·55			4·8	11·9	12·9	14·5	17·7	22·6	23·6	26·55	14	16	3+16	2+15	146	♀ iv	0+32	56
12	1·5			4·6	11·4	11·95	13·95	16·8	22·1	23·1	25·8	14	17	2+17	2+16	139	♂ v	0+33	56
13	1·53			4·7	11·4	12·55	14·25	17·6	22·65	23·7	26·3	15	16	3+17	3+15	162	♂ v	0+33	56
14	1·5			4.7	11·4	12·0	14·0	16·9	21·9	23·0	25·8	14	18	3+17	2+16	142	♀ iv	0+32	55
15	1·5			4·8	11·75	12·05	14·4	17·3	22·3	23·4	25·9	15	17	2+17	2+18	148	♂ iv–v	1+32	56
16	1·52			4·7	11·5	12·05	14·3	17·05	22·0	23·2	25·7	14	16	3+17	2+14	159	♂ v	1+32	56
17	1·5			4·8	12·3	12·55	15·2	18·0	23·0	24·25	26·9	16	16	2+17	3+16	172	♀ iv–v	1+32	55
18	1·5			4·7	11·15	11·75	14·9	16·6	21·7	22·8	25·2	15	17	3+16	2+15	117	♂ iii–iv	1+32	55
19	1·56			4·7	11·5	12·5	14·0	17·3	22·0	23·3	25·8	14	17	2+16	2+15	152	♀ iii–iv	2+31	56
20	1·5			4·6	11·25	12·15	13·8	16·9	21·85	23·0	25·6	15	17	2+17	2+15	114	♂ iii	†1+32	56
21	1·6			4·9	11·95	12·35	14·85	17·4	22·6	23·7	26·6	13	16	3+17	2+16	152	♀ iv–v	1+32	56
22	1·46			4·6	12·15	12·65	14·9	17·45	22·8	24·0	26·45	13	17	2+17	3+16	158	♀ iv–v	2+31	56
23	1·47			4·6	11·2	12·4	13·95	17·3	22·0	23·25	25·8	15	16	3+17	3+15	135	♀ iv	0+33	56
24	1·43			4·46	11·3	11·9	14·1	16·7	21·8	22·95	25·65	13	16	3+16	2+16	140	♀ iv	1+32	55
25	1·53			4·66	11·65	12·6	14·45	17·4	22·2	23·35	26·15	15	16	3+16	3+14	166	♂ v	1+32	56
26	1·35			4·2	10·25	10·6	12·5	15·05	19·3	20·4	22·7	14	17	3+17	2+16	95	♀ ii –iii	1+31	55
27	1·6			5·2	12·4	13·05	15·3	18·5	23·9	25·2	27·9	15	16	2+16	2+17	165	♂ v	1+33	57
28	1·4			4·25	10·35	10·85	12·55	15·3	20·05	21·1	23·6	15	17	2+16	2+14	104	♂ iii	0+32	56

29	1·47			4·8	11·7	12·7	14·35	17·15	22·3	23·55	26·2	14	16	2+17	2+15	139	♀ v–vi	1+32	56
30	1·43			4·5	10·6	11·4	13·4	15·8	20·8	21·9	24·3	14	16	2+17	3+15	113	♀ iii–iv	2+31	55
31	1·7			5·0	12·1	12·9	14·8	18·2	23·3	24·5	27·0	15	16	2+16	1+15	122	♀ vi	1+32	56
32	1·55			4·7	11·5	12·4	14·35	17·2	22·2	23·3	26·2	15	17	2+17	2+14	120	♂ iii	1+31	54
33	1·4			4·4	10·1	11·3	12·75	15·5	20·3	21·3	23·9	15	17	3+16	2+16	93	♂ iii	1+33	56
34	1·43			4·58	11·7	12·35	14·2	17·45	22·45	23·7	26·3	15	17	3+16	3+13	124	♀ iv	0+32*	55
35	1·68			5·15	12·45	13·6	15·15	19·1	24·6	25·8	28·7	15	16	2+17	2+14	183	iv–v	1+31	56
36	1·3			4·1	10·05	11·0	12·4	15·4	19·85	20·9	23·35	15	16	2+16	2+15	90	♂ iv	0+33	56
37	1·42			4·3	10·45	11·5	12·9	16·0	20·45	21·65	24·1	15	18	2+17	3+14	120	♀ v–vi	2+32	56
38	1·27			4·2	10·3	11·3	12·9	15·9	20·5	21·5	23·85	14	16	2+17	2+16	105	♀ iv	0+32	55
39	1·3			4·2	9·8	10·6	12·05	14·85	19·6	20·6	22·8	14	16	2+17	2+16	95	♂ iv	1+33	57
40	1·4			4·4	11·1	11·8	13·7	16·8	21·7	22·85	25·55	15	17	3+17	3+16	137	♂ iv	1+32	56
41	1·4			4·3	10·6	11·3	13·0	15·95	20·6	21·7	24·2	13	17	3+15	2+15	115	♂ iv–v	1+31	55
42	1·5			4·45	10·85	11·45	13·3	16·3	21·05	22·05	24·6	14	16	2+17	2+16	106	♂ iii	2+31	56
43	1·6			5·1	12·55	13·75	15·9	19·1	24·55	25·9	28·7	15	17	2+17	3+16	186	♀ v	1+32	56
44	1·25			4·0	9·45	10·3	11·9	14·65	19·1	20·15	22·4	15	16	3+16	2+16	185	vi iii	†0+32	55
45	1·5			4·4	10·75	11·3	13·2	15·95	20·9	22·0	24·4	15	17	2+17	2+17	115	♀ iv–v	0+33	56
46	1·43			4·5	10·8	11·7	13·3	16·4	21·3	22·35	24·8	15	17	3+17	2+15	99	♀ ii–iii	1+32	56
47	1·6			4·9	12·15	13·2	15·05	18·45	23·6	24·8	27·45	15	16	2+16	1+14	165	♀ v	0+32	56
48	1·5			4·8	11·7	12·2	14·7	17·6	22·8	23·95	26·55	17	17	3+17	2+13	144	♀ iv	1+32	56
49	1·48			4·8	12·3	12·8	15·0	18·2	23·0	24·2	26·8	14	17	3+16	2+16	142	iv–v	1+31	56
50	1·6			5·1	12·6	13·6	15·75	19·05	24·9	26·2	29·1	14	16	3+16	2+16	193	♀ v	1+33	57
51	1·43	2·06	2·58	4·6	11·1	11·5	13·55	16·2	21·35	22·5	25·2	16	17	2+16	2+16	123	♂ iv	0+33	56
52	1·6	2·2	2·8	5·05	11·9	12·8	14·9	17·9	23·1	24·2	27·05	15	18	2+17	2+14	157	♂ iv–v	1+32	56
53	1·4	2·0	2·43	4·45	11·3	11·9	14·0	17·25	22·4	23·5	26·2	15	17	3+16	2+15	147	♂ iv	0+32	55
54	1·5	2·1	2·65	4·65	11·95	12·6	14·5	17·75	23·0	24·2	26·7	15	16	2+16	2+14	163	♂ v	1+33	56
55	1·32	1·86	2·3	4·25	10·2	11·1	12·5	15·45	20·0	21·05	23·6	15	16	2+17	2+14	94	♀ vi	0+32	55
56	1·5	1·96	2·6	4·6	11·0	11·7	13·8	16·5	21·5	22·7	25·25	14	17	2+18	2+16	126	♂ iv–v	1+31	55
57	1·3	1·86	2·32	4·3	10·3	11·1	13·05	16·0	20·9	22·0	24·5	16	18	2+17	2+15	122	♀ iii–iv	0+33	56
58	1·3	1·84	2·4	4·1	9·75	10·05	11·9	14·4	18·7	19·75	21·95	15	18	2+17	3+16	81	♂ ii–iii	1+32	55
59	1·5	2·05	2·6	4·7	11·9	12·35	14·7	17·4	22·7	23·9	26·55	14	16	2+17	2+17	149	♂ v	0+33	57
60	1·4	2·05	2·55	4·55	11·3	11·8	14·0	16·5	21·8	22·9	25·45	15	18	3+17	2+17	141	♂ v	0+33	56
61	1·6			5·0	12·25	12·9	15·2	18·1	23·2	24·45	27·2	15	17	3+17	2+14	153	♂ v	2+31	56
62	1·45			4·7	11·15	12·35	13·8	16·9	21.9	23·0	25·6	14	16	2+17	2+15	128	♂ v	0+32	56
63	1·65			5·05	12·5	13·35	15·6	18·5	24·0	25·25	28·2	14	18	3+16	3+16	180	v	1+32	56
64	1·3			4·3	10·8	11·45	13·3	15·85	20·7	21·9	24·4	15	17	2+16	2+14	116	♂ v	0+32	55
65	1·5			4·75	11·7	12·5	14·45	17·6	22·55	23·7	26·4	15	17	2+17	2+15	135	♂ v	1+32	56
66	1·55			4·75	11·45	12·35	14·15	17·2	21·85	23·1	25·9	14	17	2+17	3+15	121	♀ v	2+31	55
67	1·45			4·45	10·8	11·1	13·1	16·15	20·75	21·9	24·4	15	16	2+16	2+16	116	♀ iii–iv	2+31	56
68	1·36			4·35	10·3	11·15	12·8	15·3	20·25	21·3	23·7	15	16	2+17	2+15	94	♂ iii–iv	1+31	56
69	1·55			4·8	11·4	11·9	14·0	16·55	21·55	22·8	25·2	14	18	2+17	2+15	129	♂ v	0+32	55
70	1·45			4·35	10·4	10·8	12·95	15·45	20·1	21·1	23·7	15	16	3+17	3+15	108	♂ v	1+32	56

No. of fish.	1	1a	1b	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
71	1·47			4·75	11·75	12·7	14·7	17·4	22·8	23·8	26·6	14	18	2+17	2+18	151	♂ v	2+33	57
72	1·5			4·75	11·7	12·2	14·4	17·55	22·2	23·4	26·05	15	16	2+16	2+14	147	♂ v	1+32	56
73	1·62			5·05	12·3	13·5	15·4	18·4	23·8	25·05	28·1	15	16	2+17	1+16	177	♂ v–vi	1+33	56
74	1·48			4·6	10·95	11·5	13·6	16·6	21·3	22·45	25·1	15	18	3+17	3+15	127	iv–v	1+31	56
75	1·45			4·75	11·9	12·9	14·65	17·9	23·25	24·5	27·1	14	18	2+16	2+15	165	v	0+32	55
76	1·6			5·15	13·15	13·85	16·15	19·5	24·6	25·8	28·5	15	16	3+16	3+14	171	v	1+33	56
77	1·45			4·6	11·05	12·0	13·7	16·9	21·9	22·95	25·5	15	17	1+17	3+14	124	♀ iv–v	2+32	56
78	1·6			4·95	12·75	13·5	15·75	19·1	24·4	25·6	28·35	16	17	2+17	2+16	176	♂ iv–v	0+32	56
79	1·36			4·3	10·25	10·9	12·85	15·45	19·95	21·0	23·35	16	17	2+17	2+16	109	♂ iv	3+30	55
80	1·6			5·2	12·1	13·0	14·8	17·85	23·35	24·5	27·3	13	16	3+16	2+15	150	♂ v	1+32	56
81	1·5			4·65	11·45	11·85	14·1	16·9	21·9	23·05	25·7	15	16	2+17	2+16	129	♀ iv–v	0+32	56
82	1·48			4·65	11·0	11·8	13·75	16·5	21·45	22·6	25·2	15	17	3+16	2+14	124	♀ vi	1+31	55
83	1·45			4·45	10·75	11·35	13·4	16·2	21·0	22·2	24·4	15	17	2+16	2+15	125	v–vi	1+32	55
84	1·37			4·3	10·6	11·45	13·2	16·25	21·15	22·3	24·8	15	17	3+16	2+16	95	vi–iii	1+32	55
85	1·4			4·4	10·2	10·9	12·8	15·1	19·85	20·95	23·35	14	17	2+15	1+16	99	♀ iii	1+32	56
86	1·35			4·25	10·35	11·05	12·9	15·45	20·4	21·5	24·0	14	17	2+18	3+16	101	vi–iv	0+32	55
87	1·38			4·3	10·55	11·25	13·0	15·7	20·5	21·65	24·0	15	16	2+16	2+16	114	♂ iv–v	1+32	57
88	1·55			5·0	12·2	13·1	15·15	18·15	23·5	24·75	27·55	15	17	2+17	2+15	164	♂ v	0+33	56
89	1·37			4·5	10·8	11·7	13·5	16·1	20·65	21·75	24·35	14	16	2+16	2+15	114	♀ v–vi	2+31	55
90	1·35			4·3	10·4	11·1	13·0	15·5	20·05	21·1	23·4	14	17	2+16	2+16	97	iv	1+32	55
91	1·3			4·35	10·7	11·2	13·1	15·75	20·85	22·0	24·45	15	16	3+15	3+15	111	♂ iv	0+33	56
92	1·42			4·63	11·6	12·2	14·3	17·6	22·4	23·6	26·1	15	15	2+16	2+14	153	♂ iv	1+33	56
93	1·4			4·38	10·8	11·45	13·3	16·4	21·2	22·3	24·75	14	17	2+16	2+15	119	♂ v–vi	3+31	56
94	1·4			4·4	10·85	11·9	13·5	16·6	21·55	22·6	25·1	15	17	2+17	2+14	119	iv	†1+32	56
95	1·7			5·2	12·4	13·8	15·55	19·1	24·3	25·65	28·2*	14	17	2+17	2+17	199	♂ v	2+30	55
96	1·3			4·25	10·05	10·9	12·45	15·35	20·1	21·25	23·55	14	17	2+16	2+17	98	♂ iii–iv	1+33	56
97	1·52			4·9	11·95	12·65	14·6	18·2	22·9	24·15	26·85	16	17	2+16	2+14	142	♂ iv	0+32	55
98	1·4			4·4	10·45	10·9	12·7	15·2	20·2	21·25	23·9	13	17	2+17	2+16	97	♀ vi–iv	0+31*	54
99	1·4			4·45	11·15	11·7	14·15	17·1	21·9	23·0	25·6	15	17	2+17	2+14	133	♀ v–vi	1+32	56
100	1·45			4·65	11·6	12·0	14·3	17·4	22·1	23·2	25·75	15	16	2+16	2+14	127	♂ iv–v	0+32	55
101	1·4	1·85	2·45	4·3	10·8	11·3	13·4	15·8	20·85	22·0	24·4	15	16	2+17	2+15	101	♀ vi	2+31	56
102	1·34	1·8	2·4	4·35	10·2	10·95	12·75	15·3	20·1	21·1	23·5	15	17	1+17	2+15	98	♂ v	1+32	57
103	1·35	1·92	2·43	4·4	10·15	10·75	12·4	15·1	20·0	21·1	23·5	14	16	1+17	2+16	85	♂ iv	0+33	56
104	1·73	2·3	2·96	5·3	12·4	13·3	15·6	18·8	24·2	25·55	28·5	15	17	2+17	2+15	171	♂ v	2+32	57
105	1·64	2·15	2·88	5·0	12·3	13·25	15·4	18·3	23·65	25·0	27·7	14	16	2+17	2+15	162	♂ v	1+31	55
106	1·55	2·13	2·7	4·75	11·45	12·05	14·25	17·05	21·8	22·9	25·7	14	17	2+17	2+16	163	♀ iv–v	2+31	55
107	1·42	1·95	2·43	4·55	11·1	11·75	13·7	16·6	21·7	22·75	25·4	15	17	2+17	1+15	156	♂ v	1+32	56
108	1·52	1·96	2·6	4·7	11·7	12·8	14·4	18·05	23·1	24·3	27·0	14	16	3+16	1+15	144	♀ iv–v	1+31	55
109	1·56	2·08	2·74	4·8	11·7	12·4	14·6	17·3	22·5	23·65	26·5	14	17	2+16	3+15	147	♂ v	1+31	55

110	1·7	2·2	3·0	5·05	12·2	13·2	15·1	18·2	23·4	24·7	27·5	15	16	2+16	3+14	156	♂ v	2+30	55
111	1·54			4·5	11·2	11·8	14·2	16·6	21·6	22·75	25·35	14	16	3+17	3+14	131	iii–iv	1+31	55
112	1·4			4·25	10·45	11·7	12·9	16·2	21·0	22·2	24·65	14	17	2+16	1+16	114	♀ vi	2+32	56
113	1·5			4·6	11·05	12·1	13·7	16·5	21·5	22·65	25·05	14	15	2+17	2+15	120	iv–v	1+32	55
114	1·58			4·74	11·2	12·15	14·25	17·05	22·4	23·55	26·3	15	17	2+18	1+17	143	♂ iii–iv	1+32	56
115	1·4			4·65	11·1	11·8	13·9	16·6	21·5	22·6	25·3	15	18	3+16	2+14	116	♂ iv–v	0+32	55
116	1·6			4·9	11·7	12·8	14·8	17·7	22·9	24·05	26·9	15	16	2+17	2+15	159	♂ v	1+32	56
117	1·58			5·1	12·75	14·0	15·9	19·15	24·65	25·95	28·85	14	18	2+17	2+16	213	♂ v	2+32	56
118	1·45			4·65	11·4	12·25	14·5	17·15	22·2	23·2	26·05	14	17	2+18	2+15	122	♂ v	†0+33	56
119	1·5			4·85	12·2	13·0	15·15	18·5	23·8	25·0	27·8	15	17	2+17	2+16	172	♂ v	0+33	56
120	1·63			5·1	12·8	13·4	15·7	19·05	24·25	25·45	28·3	14	17	2+16	2+15	176	♀ iv–v	0+32	55
121	1·4			4·65	11·05	11·55	13·7	16·35	21·3	22·45	24·95	14	18	2+17	3+14	120	♂ iv	1+33	56
122	1·33			4·5	11·0	11·8	13·6	16·8	21·65	22·75	25·5	16	16	2+16	1+13	117	iv–v	0+33	55
123	1·46			4·76	11·3	11·7	13·85	16·55	21·8	22·85	25·5	14	17	2+17	2+14	128	v	1+32	55
124	1·5			4·5	10·9	11·5	13·55	16·3	21·2	22·3	25·0	15	16	2+16	2+16	123	♂ iv–vi	1+31	55
125	1·5			4·55	11·4	12·15	14·1	17·1	22·1	23·25	25·9	15	17	3+17	3+16	121	♀ iv	1+33*	57
126	1·7			5·3	12·9	13·5	15·85	19·2	24·7	25·8	28·9	15	16	2+16	2+16	174	♂ v–vi	2+32	56
127	1·5			4·8	12·0	13·0	14·9	18·7	23·55	24·7	27·4	15	17	3+17	2+15	169	♂ v	0+33	56
128	1·4			4·47	11·5	12·4	14·2	17·4	22·5	23·6	26·3	15	16	2+17	2+14	144	♀ v	2+31	56
129	1·5			4·5	10·8	11·6	13·5	16·3	21·45	22·5	24·95	15	17	2+17	2+15	120	♀ vi	0+32	56
130	1·6			5·1	12·4	12·9	15·5	18·45	23·8	25·05	28·05	15	17	2+18	2+16	189	♂ v–vi	1+32	56
131	1·4			4·5	10·9	11·3	13·6	16·1	21·15	22·25	24·8	15	17	2+17	2+16	114	♂ iv–v	0+34	56
132	1·55			4·75	11·4	11·9	14·05	16·8	21·7	22·85	25·6	15	17	2+17	2+15	131	♀ iv–v	2+31	55
133	1·38			4·35	10·55	11·4	12·95	15·75	20·65	21·7	24·2	14	17	2+16	2+16	112	iv–v	†0+33	56
134	1·65			4·8	11·2	12·3	14·25	17·2	22·7	23·9	26·7	14	16	2+17	2+16	168	♀ v	0+32	55
135	1·4			4·5	10·65	11·4	13·2	16·2	21·1	22·1	24·7	15	18	3+16	2+15	124	♀ iv	1+33	57
136	1·6			5·15	12·0	12·8	14·9	17·8	23·0	24·25	27·05	14	16	2+16	2+15	132	♂ iii	1+31	56
137	1·5			4·7	11·4	12·25	14·1	17·15	22·05	23·25	25·95	14	16	2+16	1+15	137	v	2+32	57
138	1·7			5·0	12·4	13·3	15·3	18·4	23·75	25·1	27·9	15	17	3+17	2+16	172	♂ v	1+32	56
139	1·5			4·7	11·4	11·8	14·2	16·7	21·85	23·0	25·65	15	17	2+17	2+15	134	♂ iii–iv	2+30*	56
140	1·7			5·1	12·0	13·5	14·9	18·5	23·5	24·7	27·55	15	17	3+16	2+15	170	♀ v	1+32	56
141	1·5			4·5	10·7	11·6	13·3	15·8	20·9	21·95	24·55	15	16	2+16	3+15	115	♀ iv–v	1+31	56
142	1·4			4·5	10·85	11·6	13·7	16·5	21·5	22·5	24·9	14	17	2+17	2+17	119	♂ iv	0+32	56
143	1·5			4·86	11·6	12·4	14·35	17·5	22·75	23·95	26·65	14	17	2+17	2+16	157	♀ vi	†0+34	56
144	1·55			4·65	11·7	12·1	14·55	17·8	23·0	24·15	26·9	15	17	2+16	3+15	144	♀ vi–iv	0+32	56
145	1·5			4·7	11·55	12·45	14·3	17·5	22·8	24·0	26·75	14	16	2+16	3+15	146	♂ v	2+30	55
146	1·47			4·6	11·0	11·7	13·65	16·6	21·85	22·95	25·65	15	16	2+17	2+16	123	♂ iv	0+33	56
147	1·44			4·73	11·5	11·75	14·3	16·9	22·05	23·1	25·8	15	16	2+17	2+15	132	♂ iv	†0+32	56
148	1·5			4·7	11·55	12·7	14·25	17·8	22·85	24·1	26·6	15	16	2+18	2+15	130	♂ ii	1+32	56
149	1·5			4·6	11·5	12·2	14·3	17·45	22·75	23·9	26·55	15	16	3+16	2+16	159	♀ v	1+32	56
150	1·5			4·7	12·1	13·0	14·9	18·1	23·5	24·7	27·5	15	17	3+16	2+16	164	♀ iv–v	1+32	56
151	1·35			4·3	10·3	11·3	12·7	15·5	20·45	21·55	24·0	14	16	2+16	2+15	103	♂ iii	0+34	57

No. of fish.	1	1a	1b	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
152	1·24			4·15	9·95	11·1	12·4	15·3	20·0	21·0	23·5	15	17	2+17	3+15	103	♂ iii–iv	1+32	56
153	1·45			4·45	10·6	11·8	13·55	16·5	21·5	22·6	25·3	14	17	3+17	2+15	127	♀ iv–v	1+32	56
154	1·43			4·6	11·55	12·3	14·45	17·6	22·8	23·9	26·7	15	16	2+16	2+16	152	♀ v	1+32	56
155	1·4			4·85	11·8	12·5	14·65	17·65	22·95	24·2	26·95	15	17	3+16	2+17	171	♀ iv–v	1+32	56
156	1·65			5·05	12·4	12·9	15·25	18·4	23·55	24·8	27·8	15	16	2+17	2+15	171	♀ v	1+32	56
157	1·47			4·7	11·35	11·7	14·15	16·7	22·1	23·2	25·75	16	17	2+17	2+14	119	♂ iii	*1+0+32	57
158	1·5			4·6	11·0	12·15	13·65	16·7	21·75	22·8	25·4	14	17	2+16	2+15	117	♂ iv	0+32	55
159	1·63			4·9	11·6	12·45	14·65	17·6	22·8	23·95	26·85	14	15	2+17	2+16	137	♂ iii	1+32	56
160	1·5			4·55	10·8	11·75	13·4	16·35	21·3	22·45	25·05	15	17	2+18	2+16	107	♀ vi–iv	2+31	55
161	1·4			4·4	11·05	11·7	13·5	17·0	21·4	22·6	25·3	15	16	2+16	3+14	138	♂ v	1+31	*?
162	1·44			4·6	11·35	12·35	14·25	17·7	22·55	23·75	26·3	14	16	2+16	2+16	157	iv–v	1+32	56
163	1·43			4·35	10·8	11·65	13·25	16·3	21·05	22·2	24·6	14	16	2+16	2+14	113	♂ iii–iv	1+32	56
164	1·33			4·5	10·8	11·45	13·9	16·5	21·15	22·55	25·25	15	16	2+17	2+16	134	♂ v–vi	1+32	55
165	1·72			5·05	12·75	13·05	15·5	18·65	24·0	25·3	28·2	15	17	2+16	3+15	185	v	1+32	56
166	1·35			4·5	11·0	10·9	13·4	16·2	21·4	22·45	25·1	16	17	2+16	2+16	121	♀ vi	2+33	56
167	1·36			4·14	9·8	10·75	12·3	14·8	19·35	20·4	22·9	‡—+11	17	2+16	2+16	88	♂ v	1+31	55
168	1·55			4·55	11·0	11·15	13·6	16·5	21·4	22·5	25·0	15	17	2+16	2+16	110	♂ iv–v	0+33	56
169	1·43			4·55	11·05	11·45	13·9	16·65	21·6	22·75	25·6	15	17	2+17	2+16	138	♀ v	1+32	55
170	1·6			4·65	11·5	12·4	14·1	17·3	22·5	23·7	26·4	15	16	2+16	2+14	156	♀ vi	1+32	56
171	1·4			4·5	11·25	12·05	14·0	17·2	22·2	23·35	25·9	16	18	2+16	2+14	146	♂ iv–v	1+33	56
172	1·4			4·35	10·35	11·1	12·85	15·8	20·5	21·65	23·9	15	17	2+17	2+15	108	iv–v	†0+33	56
173	1·4			4·4	10·3	10·9	12·85	15·45	20·25	21·25	23·8	15	16	2+18	2+14	94	♀ vi–iv	1+32	56
174	1·45			4·6	11·3	12·0	13·85	17·1	22·3	23·4	26·05	16	16	2+16	3+13	128	♀ vi	1+33	56
175	1·46			4·6	11·4	11·9	14·1	16·75	21·65	22·75	25·4	14	17	3+16	2+16	154	♀ v	1+31	55
176	1·5			4·75	11·45	11·9	14·25	17·15	22·4	23·55	26·2	15	16	3+17	2+16	131	iv–v	1+31	55
177	1·4			4·25	10·15	11·05	12·7	15·7	20·15	21·25	23·7	16	15	2+17	2+15	107	♂ v	0+32	56
178	1·5			4·65	11·5	12·0	14·15	16·5	22·0	23·15	25·65	14	16	2+17	2+17	111	♀ vii	1+32	56
179	1·48			4·7	11·1	12·15	13·85	16·6	21·75	22·95	25·7	15	17	3+16	2+15	129	♀ iv–v	0+31	56
180	1·6			5·1	12·3	13·1	15·4	18·7	23·9	25·2	27·9	15	18	2+17	2+15	154	♂ v–vi	1+32	56
181	1·5			4·85	11·85	12·65	14·75	17·55	22·55	23·7	26·3	15	15	2+17	2+15	140	♀ v	1+32	56
182	1·4			4·6	10·6	11·2	13·1	16·05	20·6	21·7	24·15	16	16	2+17	2+15	94	♂ iii	2+31	56
183	1·4			4·5	11·1	11·9	13·85	16·75	21·85	22·95	25·4	15	17	3+16	2+15	122	♀ vi–iii	0+32	55
184	1·8			5·3	12·85	13·8	15·9	18·8	24·35	25·65	28·5	14	18	3+17	3+16	163	♀ v	1+32	56
185	1·65			5·1	12·05	13·3	14·95	18·1	23·25	24·4	27·3	14	17	3+16	2+15	158	♂ v–vi	0+31	55
186	1·38			4·33	9·8	10·45	12·2	14·8	19·45	20·45	22·8	15	17	2+16	2+16	90	♂ v–vi	0+33	56
187	1·5			4·6	11·0	12·3	13·5	16·85	21·8	22·95	25·7	15	17	3+16	3+16	126	♂ iv–v	0+32	56
188	1·3			4·0	9·85	10·95	12·15	15·2	19·55	20·55	22·95	15	18	3+16	2+16	97	♂ iii–iv	†0+32	55
189	1·4			4·45	10·55	11·15	13·15	15·9	20·85	21·95	24·4	15	16	2+17	2+15	101	♂ iv	1+32	56

‡ Space devoid of scales.

190	1·46	4·4	10·4	11·35	13·05	15·8	20·55	21·5	23·15 *	15	17	2	17	2	15	100		iv–v	1 32	56
191	1·54	4·65	11·65	12·25	14·3	17·3	22·3	23·4	26·15	15	18	2	17	2	15	146	♂	v	1 32	56
192	1·46	4·6	11·0	12·3	14·1	17·25	22·3	23·5	26·15	15	16	3	17	3	15	155	♂	v–vi	1 32	56
193	1·55	4·75	11·15	12·1	13·9	16·5	21·95	23·05	25·7	13	17	3	17	2	16	136		iii–iv	†0+33	57
194	1·35	4·5	11·0	11·6	13·6	16·4	21·15	22·25	24·7	15	18	2	16	2	15	116	♂	iv–v	0+33	56
195	1·3	4·15	9·95	10·8	12·45	15·05	19·55	20·6	23·0	14	16	3	17	1	16	94		iv–v	3+30	55
196	1·33	4·2	10·8	11·45	13·4	16·5	21·3	22·35	25·0	14	16	2	17	2	15	124	♀	vi–iv	†1 32	56
197	1·35	4·3	10·2	10·95	12·7	15·25	20·05	21·05	23·6	13	17	3	17	2	15	102	♂	iv	0 31	55
198	1·43	4·4	10·5	11·4	13·2	15·9	20·7	21·85	24·4	16	17	3	16	1	16	106	♂	v–vi	1 32	56
199	1·48	4·9	12·15	12·8	15·15	18·0	23·1	24·2	26·8 *	15	17	3	18	2	16	145	♂	iv–vi	†0 32	56
200	1·48	4·4	10·7	11·65	13·4	16·25	21·2	22·35	24·95	14	17	2	17	1	15	139		iv–v	2+31	56
201	1·7	5·0	11·95	12·9	15·1	17·8	23·1	24·2	27·05	14	17	3	16	2	16	163	♂	v	0+32	55
202	1·45	4·4	10·7	11·35	13·4	16·15	20·9	22·1	24·6	16	17	2	18	2	16	112		vi	1 33	56
203	1·48	4·65	11·15	12·15	13·65	17·15	22·0	23·05	25·8	15	16	2	15	2	15	142	♀	iv–v	1 33	56
204	1·44	4·7	11·0	11·6	13·5	16·5	21·55	22·7	25·2	14	16	3	17	3	15	117	♂	v	1+31	45
205	1·36	4·3	10·3	11·0	12·8	15·65	20·45	21·5	24·05	15	17	2	16	2	16	115	♂	iv–v	1+32	56
206	1·46	4·55	11·45	12·2	14·3	17·3	22·15	23·3	25·8	15	16	3	16	2	16	138	♀	vi	0 33	56
207	1·26	4·2	9·9	10·8	12·3	14·9	19·3	20·5	22·8	15	16	3	17	1	16	93	♂	v–vi	1+31	55
208	1·26	4·2	10·3	10·75	12·7	15·5	20·2	21·2	23·8	15	16	3	16	2	16	91	♂	iii–iv	0 32	56
209	1·5	4·7	11·95	12·6	14·8	17·7	22·9	24·05	26·8	14	17	3	16	2	15	154	♀	v	1 33	57
210	1·5	4·75	12·0	13·1	14·9	18·25	23·25	24·45	27·15	15	17	2	16	2	16	174	♂	v	0 34	57
211	1·36	4·4	10·5	11·5	13·3	16·1	20·9	22·05	24·55	14	16	3	17	2	15	116	♂	v–vi	†0 33	56
212	1·33	4·3	10·5	10·85	12·95	15·2	19·85	20·85	23·2	15	17	2	17	2	16	93	♂	iii	1 31	55
213	1·5	4·7	11·25	12·45	14·0	16·8	22·15	23·25	25·95	14	16	3	16	2	15	126	♀	v	1 32	56
214	1·4	4·4	10·25	10·95	12·8	15·2	19·9	20·95	23·55	15	17	3	17	2	17	91	♀	vi–iii	1 32	56
215	1·6	4·9	11·45	12·8	14·5	17·65	23·0	24·2	27·2	15	16	3	17	1	15	161	♀	vi	1 33	56
216	1·6	4·85	11·7	12·65	14·65	17·95	23·0	24·3	26·65	14	16	3	16	2	16	157	♀	v	1 31	55
217	1·75	5·35	13·2	14·6	16·6	19·9	25·8	27·15	30·2	14	17	3	17	1	16	200	♀	v	1 32	56
218	1·7	5·15	13·05	14·1	16·4	19·75	24·85	26·2	29·0	14	17	3	16	2	14	197	♀	v	1 31	55
219	1·65	5·15	12·55	13·45	15·2	18·2	23·9	25·2	27·85	14	17	3	16	2	16	169	♀	v	0 33	57
220	1·55	4·55	11·15	12·55	14·2	17·2	22·5	23·7	26·35	14	17	3	17	2	15	166	♂	v–vi	0 33	56
221	1·5	4·65	11·35	11·65	14·25	16·8	22·0	23·2	25·95	14	17	3	17	2	15	143	♀	v	2 32	56
222	1·45	4·45	10·8	11·45	13·5	16·1	21·3	22·4	25·0	15	17	3	16	2	14	119	♂	iii–iv	1 33	56
223	1·58	4·95	11·9	12·8	14·65	17·5	22·75	23·95	26·5	15	18	2	16	2	14	124	♂	iii–iv	1 32	56
224	1·46	4·5	10·5	11·0	13·0	15·75	20·45	21·55	24·15	15	17	2	17	2	15	116	♀	vi	1 31	55
225	1·4	4·5	11·1	12·0	14·05	17·15	22·3	23·4	26·0	14	16	3	17	0	15	143	♂	iv	2 31	55
226	1·3	4·36	10·85	11·45	13·5	15·9	21·15	22·35	24·9	14	17	2	17	3	16	121	♂	iv–v	1 31	55
227	1·66	5·0	11·65	12·35	14·55	17·1	22·65	23·85	26·8	14	16	3	16	1	16	167	♀	v	3 31	55
228	1·5	4·8	12·15	12·3	14·95	17·55	22·6	23·7	26·65	15	17	3	17	2	16	150	♂	v	1 32	56
229	1·4	4·45	10·9	11·65	13·55	16·55	21·35	22·45	25·05	14	17	2	17	2	15	123	♂	v	1 31	56
230	1·38	4·45	10·8	11·75	13·4	16·3	21·2	22·25	24·9	15	16	2	17	2	16	116	♂	v	1 32	56
231	1·48	4·6	11·2	11·9	12·8	16·8	21·65	22·75	25·3	15	17	2	17	2	15	118		iii	1 32	56

No. of fish.	1	1*a*	1*b*	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
232	1·5			4·9	12·1	12·25	15·0	17·65	22·75	23·95	26·6	14	16	3+16	2+16	154	♂ v	1+32	55
233	1·5			4·9	11·95	12·65	14·7	17·3	22·65	23·85	26·65	14	17	2+18	2+16	137	♀ v	1+33	56
234	1·4			4·55	11·0	11·75	13·7	16·5	21·75	22·9	25·4	15	17	2+16	2+15	123	♂ iv	0+31	55
235	1·38			4·35	10·15	10·6	12·7	15·15	19·8	20·9	23·4	14	16	2+17	2+16	95	♂ iv	1+31	55
236	1·44			4·45	10·95	11·7	13·55	16·5	21·4	22·45	24·95	15	17	2+16	0+16	124	♀ iv–v	†0+33	56
237	1·57			4·95	12·05	13·3	15·1	18·4	23·65	24·8	27·7	15	17	3+16	2+15	171	♂ v	2+31	55
238	1·6			5·1	12·5	12·95	15·5	18·3	23·7	25·1	27·9	14	17	3+16	2+16	157	♂ v	0+32	56
239	1·6			5·0	12·7	13·5	15·7	19·0	24·75	25·9	29·0	14	17	3+16	2+16	195	♀ iv–v	2+32	56
240	1·4			4·7	11·75	12·3	14·35	17·25	22·5	23·65	26·35	13	17	2+16	2+15	157	♀ v	†1+32	56
241	1·3			4·2	10·2	11·0	12·8	15·45	20·2	21·15	23·6	14	16	3+17	1+15	107	♂ iii–iv	†1+31*	54
242	1·44			4·83	11·95	12·8	14·7	18·0	23·0	24·15	26·85	15	16	2+16	1+16	156	♀ v	1+32	56
243	1·5			4·75	11·45	12·65	14·3	17·55	22·6	23·8	26·6	15	17	3+16	2+16	160	♂ iv–v	0+33*	56
244	1·65			4·95	11·85	12·6	14·9	17·6	22·95	24·15	26·9	15	17	3+17	1+16	149	♀ vi	2+31	55
245	1·53			4·95	12·5	13·3	15·65	18·45	23·8	25·0	27·85	14	18	2+17	2+15	145	♂ iii–iv	1+32	55
246	1·5			4·6	11·2	11·95	13·75	16·95	22·1	23·2	26·0	15	18	2+16	1+15	129	♂ iv	1+32	56
247	1·48			4·46	11·0	11·6	13·4	16·45	21·5	22·65	25·1	14	16	2+16	1+16	127	♀ vi	†1+32	56
248	1·4			4·35	10·45	11·6	13·15	15·9	20·7	21·75	24·2	15	17	2+17	2+16	109	♂ iv–v	1+31	55
249	1·4			4·5	11·1	12·0	13·95	16·5	21·5	22·55	25·0	14	17	3+17	1+15	126	♂ iv–v	0+32	55
250	1·58			5·0	11·55	12·5	14·6	17·4	22·8	23·95	26·8	13	17	2+18	2+16	156	♀ v	1+32	55
251	1·35			4·4	10·5	11·05	13·2	15·35	20·2	21·3	23·65	14	18	2+17	2+17	97	♀ vi–iii	0+32	56
252	1·35			4·45	11·35	11·5	13·9	16·55	21·35	22·55	25·05	15	16	2+16	2+15	127	♀ vi–iii	0+32	55
253	1·55			4·95	11·7	12·75	14·65	17·45	22·9	24·0	27·0	13	16	2+17	3+15	166	♀ v	†0+33	56
254	1·55			4·9	12·05	12·8	14·85	18·05	23·05	24·2	27·05	15	17	2+16	1+16	130	♂ ii	0+32	55
255	1·83			5·5	13·05	13·65	16·15	19·5	25·1	26·4	29·4	16	18	3+17	2+15	189	♀ v	2+30	56
256	1·45			4·5	11·0	11·95	13·85	17·0	21·95	23·0	25·6	14	16	3+17	3+15	132	♂ iv–vi	0+33	56
257	1·3			4·25	10·6	11·45	13·15	16·3	21·1	22·15	24·6	16	17	3+16	3+15	120	♂ iii–iv	0+33	56
258	1·4			4·7	11·55	12·4	14·35	17·4	22·5	23·7	26·3	15	16	3+17	2+15	137	♂ v	2+32	57
259	1·4			4·4	10·55	11·45	13·35	16·0	20·95	22·1	24·6	13	17	2+18	3+15	126	♂ v	2+32	56
260	1·7			4·25	12·85	13·65	15·65	19·0	24·15	25·45	28·2	15	16	2+16	2+14	181	♂ v	1+32	57
261	1·3			4·4	10·8	11·2	13·2	15·4	20·4	21·4	23·9	14	17	2+17	2+15	107	♂ iv–vi	1+32	55
262	1·55			4·7	11·05	12·0	13·8	16·6	21·8	22·9	25·75	15	16	3+16	2+15	139	♀ v	1+31	54
263	1·6			4·9	11·75	12·6	14·75	17·65	23·1	24·2	27·1	14	18	2+17	2+17	168	♂ v	1+33	57
264	1·35			4·5	10·5	11·2	13·15	15·5	20·8	21·9	24·6	15	16	3+17	2+16	108	♂ v	1+32	56
265	1·4			4·6	11·2	11·9	13·9	17·0	22·1	23·2	25·85	16	18	3+16	2+15	117	♀ vi–iii	1+33	56
266	1·45			4·65	11·15	11·95	13·85	16·4	21·45	22·65	25·25	14	16	3+16	2+17	118	♀ vi	0+32	55
267	1·35			4·4	10·8	11·4	13·55	16·4	21·25	22·45	24·95	15	17	2+17	2+16	116	iv–v	0+(1+1+30)	55
268	1·53			4·7	11·4	12·0	14·2	17·2	22·05	23·3	26·1	15	17	2+17	1+16	137	♀ iv–v	1+31	55
269	1·36			4·48	11·0	12·0	13·5	16·8	21·6	22·8	25·35	14	17	2+16	3+14	133	♂ v	0+33	56
270	1·35			4·35	11·05	11·5	13·5	16·3	21·25	22·25	24·75	16	16	3+16	2+15	113	♂ v–vi	†1+33	57

271	1·35		4·36	10·6	11·35	13·4	15·95	21·1	22·25	24·85	13	17	2+17	2+14	115	♂ iv–vi	0+32	56
272	1·55		4·85	11·95	13·1	15·0	18·1	23·4	24·7	27·35	15	16	3+17	2+15	166	♂ v	3+31	56
273	1·4		4·35	10·5	11·2	12·95	15·85	20·65	21·7	24·15	14	18	3+16	2+15	118	♂ v–vi	1+31	55
274	1·45		4·65	11·05	11·45	13·75	16·3	21·7	22·8	25·5	15	16	2+17	3+16	123	♂ v–vi	2+31	56
275	1·4		4·3	9·95	10·7	12·35	14·9	19·55	20·6	23·0	15	17	2+17	3+15	95	♀ iv–v	0+33	56
276	1·5		4·54	11·05	11·8	13·8	16·35	21·45	22·55	24·95	13	17	2+16	2+16	120	♂ v–vi	†0+32	55
277	1·43		4·55	11·25	11·85	14·1	16·9	21·7	22·9	25·3	15	18	3+16	2+15	123	♂ iv–v	1+32*	56
278	1·72		5·3	12·4	13·75	15·5	18·85	24·3	25·75	28·6	14	17	3+16	2+15	170	♀ v	1+31	55
279	1·4		4·5	11·35	11·7	14·2	16·95	21·95	23·05	25·75	15	17	2+17	2+15	123	♂ v	2+31	55
280	1·6		4·9	12·0	12·8	14·7	17·9	23·1	24·35	27·15	15	17	3+16	3+15	170	♂ v	1+31	56
281	1·53		4·7	11·3	11·95	13·85	16·6	21·5	22·6	25·3	13	17	2+16	3+15	128	♀ v–vi	1+31	55
282	1·3		4·1	10·5	11·45	13·15	16·15	20·9	22·1	24·5	14	16	2+17	3+15	115	♀ v–vi	0+32	56
283	1·38		4·42	10·85	11·4	13·35	16·15	21·25	22·35	24·85	15	15	2+16	3+15	103	♀ vi–iv	1+32	56
284	1·35		4·25	10·0	10·8	12·35	14·8	19·7	20·75	23·25	15	17	2+17	2+17	92	♂ iv–v	0+32	55
285	1·44		4·3	10·3	10·9	12·65	15·5	20·1	21·15	23·7	15	18	2+16	2+17	95	♂ iv–v	†0+32	56
286	1·4		4·4	10·45	11·1	13·1	15·35	20·5	21·55	24·0	9+0+5	16	3+16	3+16	102	♀ iii–iv	2+32	56
287	1·76		5·15	12·4	12·95	15·3	18·3	23·75	24·95	27·6	16	17	3+16	3+15	172	♂ v	2+31	56
288	1·5		4·55	11·05	11·6	13·55	16·45	21·35	22·45	25·1	16	18	2+15	2+15	119	♂ v	0+31*	56
289	1·48		4·65	11·45	12·1	14·2	16·9	22·2	23·4	25·95	14	18	3+17	2+15	130	♂ v	2+31	56
290	1·35		4·3	10·7	11·4	12·9	15·95	20·7	21·85	24·4	16	17	2+16	2+15	111	♀ v	†0+33	57
291	1·4		4·48	11·05	11·6	13·6	16·2	21·25	22·4	25·05	15	16	2+17	2+15	113	♀ vi	1+31*	56
292	1·55		4·85	11·95	12·75	14·95	18·05	23·2	24·4	27·2	1+14	16	2+18	2+15	160	♀ v	0+33	57
293	1·3		4·3	10·2	10·9	12·6	15·15	19·8	20·85	23·3	14	17	2+17	3+14	107	♂ iv–v	1+32	55
294	1·35		4·25	10·4	11·25	13·1	15·8	20·85	22·05	24·55	15	16	3+16	2+16	123	♂ v–vi	1+32	55
295	1·54		4·6	11·3	12·0	14·1	17·2	22·25	23·35	26·0	15	16	2+17	2+16	128	♀ iv–v	0+33	56
296	1·34		4·05	9·95	10·2	12·15	14·7	19·2	20·3	22·55	15	17	3+15	2+16	84	♂ iii–iv	2+31	56
297	1·5		4·85	11·75	12·8	14·6	17·5	22·65	23·75	26·45	16	18	2+17	2+14	133	♂ iv–vi	2+32	57
298	1·58		4·9	12·0	12·6	14·95	17·9	22·9	24·15	26·8	15	17	3+16	2+15	178	♂ v	2+32	56
299	1·5		4·65	11·45	12·45	14·45	17·2	22·45	23·7	26·35	14	17	3+17	2+15	125	♀ iv–v	1+32*	56
300	1·48		4·65	11·65	12·35	14·4	17·3	22·35	23·7	26·15	15	17	2+17	2+14	158	♂ v–vi	†0+31	55
301	1·48		4·55	11·1	11·65	13·6	16·95	21·8	22·95	25·7	16	16	2+16	3+15	136	♂ v–vi	2+31	55
302	1·4		4·2	10·5	11·1	12·95	15·85	20·3	21·5	24·0	15	17	3+16	2+15	114	♂ v	0+33	56
303	1·6		5·0	11·9	13·0	14·7	18·0	23·35	24·65	27·25	16	16	2+16	2+15	158	♀ vi	0+34	56
304	1·4		4·45	11·1	12·0	13·8	16·75	21·55	22·7	25·5	15	17	2+17	2+15	120	♂ iv–v	0+32	55
305	1·3		4·0	9·75	10·45	12·05	14·65	19·2	20·3	22·45	14	16	2+17	3+16	85	♀ vi–iii	1+32	56
306	1·5		4·9	12·35	12·8	15·15	18·2	23·6	25·0	27·6	15	17	2+16	2+16	176	♂ v	1+31	55
307	1·5		4·8	11·5	12·2	14·25	17·4	22·4	23·6	26·4	15	16	2+16	1+15	156	♀ v	0+32	56
308	1·4		4·4	10·45	11·15	13·1	16·0	20·8	21·9	24·5	14	17	3+17	1+15	117	♀ iii–iv	1+33	56
309	1·44		4·58	11·3	11·5	13·9	16·8	21·85	23·0	25·6	15	17	2+17	2+17	123	♀ v	0+32	55
310	1·4		4·48	10·95	11·45	13·9	15·8	21·2	22·39	24·95	14	17	3+17	2+16	128	♂ v	2+31*	56
311	1·3		4·3	10·2	11·0	12·75	15·55	20·2	21·3	23·6	15	18	2+17	2+16	93	♂ iv–v	†0+32	55
312	1·32		4·2	10·6	11·25	13·15	15·85	20·6	21·7	24·05	17	17	2+17	2+17	101	♂ iv–v	†0+32	56

No. of fish.	1	1*a*	1*b*	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
313	1·34			4·55	10·95	11·7	13·6	16·65	21·7	22·8	25·5	16	17	2+16	2+15	125	♂ v	0+33	56
314	1·3			4·4	10·7	11·65	13·5	16·5	21·3	22·55	25·0	14	17	2+16	2+15	121	♂ v–vi	1+31	54
315	1·44			4·5	10·75	11·4	13·35	16·15	21·05	22·3	24·75	15	17	2+16	2+16	110	♂ iv–vi	†0+33	56
316	1·6			4·95	11·75	12·7	14·4	17·55	22·8	24·05	26·9	1+14	17	2+17	2+15	152	♀ vi	1+32*	56
317	1·5			4·7	11·9	12·6	14·75	17·75	22·8	24·0	26·65	15	16	2+17	3+15	136	♀ vii	†0+32	56
318	1·33			4·2	10·25	10·7	12·55	15·65	20·35	21·4	23·9	16	17	3+16	2+14	97	♂ iv–vi	1+32	56
319	1·48			4·7	11·2	12·2	13·75	17·25	21·15	23·3	25·9	16	18	2+17	2+15	128	♂ iv–vi	1+33	57
320	1·7			4·95	11·65	12·6	14·45	17·95	23·05	24·3	27·3	15	17	2+16	2+15	166	♂ v	0+32	56
321	1·26			4·15	10·3	10·8	13·0	15·25	19·8	20·9	23·3	14	16	2+16	1+15	95	♀ vi–iv	†0+33	56
322	1·52			4·8	11·4	12·5	14·2	17·15	22·3	23·45	25·95	14	17	3+17	1+16	129	♂ v	2+31	56
323	1·32			4·3	10·15	10·85	12·8	15·4	20·2	21·25	23·65	15	17	3+17	2+17	110	♂ iv–vi	†1+31	55
324	1·6			4·8	11·8	12·7	14·75	17·65	23·0	24·2	26·95	16	17	2+18	1+15	168	♂ v	†1+30	56
325	1·49			4·4	10·75	11·8	13·4	16·35	21·35	22·5	24·8	15	16	2+17	2+15	110	♂ iv–vi	1+32	55
326	1·66			5·2	12·65	13·7	15·55	18·65	24·35	25·7	28·5	14	16	2+17	2+16	165	♂ iv–v	0+33	56
327	1·6			5·0	12·3	13·5	15·3	18·55	24·25	25·5	28·6	15	18	2+17	2+16	177	♀ v	1+32	56
328	1·38			4·45	11·35	12·2	14·15	17·2	22·35	23·5	26·0	15	17	2+17	2+15	141	♂ v	1+33	56
329	1·48			4·5	10·85	12·25	13·5	16·6	21·75	22·95	25·7	14	17	2+16	1+17	134	♂ v	0+33	56
330	1·5			4·6	10·9	11·7	13·55	16·3	21·25	22·35	24·9	14	18	2+17	2+15	111	♀ vi	1+31	55
331	1·55			4·65	11·4	12·15	14·15	17·1	22·1	23·3	25·95	14	17	2+17	2+15	161	♀ iv–v	0+34	56
332	1·58			4·8	11·95	12·65	14·75	17·8	23·0	24·2	27·05	15	17	3+16	2+15	156	♀ v	2+32	56
333	1·6			4·85	11·1	12·5	13·65	16·85	22·05	23·15	25·95	15	17	3+16	2+14	124	♀ i–ii	2+31	56
334	1·43			4·55	10·7	11·4	13·5	16·05	21·0	22·2	24·95	15	17	2+18	2+15	114	♀ iv–v	2+31	55
335	1·36			4·32	11·05	11·7	13·75	16·6	21·4	22·5	25·1	15	17	2+17	2+16	138	♂ v	2+31	55
336	1·4			4·5	11·5	12·35	14·45	17·7	22·35	23·6	26·25	15	17	3+16	2+15	138	♂ v	0+31	55
337	1·38			4·45	11·1	11·65	13·95	16·9	21·75	23·05	25·65	14	17	2+17	2+15	151	♂ v	2+31	56
338	1·3			4·25	10·1	11·1	13·25	16·05	20·8	21·9	24·35	16	16	2+18	2+16	118	♂ iv–vi	0+32	56
339	1·4			4·55	11·6	12·45	14·4	17·7	22·7	23·95	26·75	14	17	2+17	2+15	152	♂ v	0+33	56
340	1·45			4·4	10·65	11·45	13·4	16·05	20·7	21·8	24·3	15	18	2+17	2+15	114	♂ iii–iv	1+32	56
341	1·5			4·55	10·65	11·4	13·4	15·85	21·95	22·1	24·65	13	17	3+17	2+17	104	♂ iii–iv	0+34	56
342	1·5			4·68	11·6	12·1	14·25	17·1	22·5	23·8	26·3	15	17	3+16	1+16	133	♂ v	2+32	56
343	1·4			4·5	10·95	11·95	13·7	16·75	21·85	23·0	25·7	16	17	2+17	2+16	118	♂ iv–vi	1+33	57
344	1·4			4·28	10·6	11·4	13·1	16·25	21·15	22·25	24·8	15	17	2+17	2+16	113	♂ iv–vi	1+34	57
345	1·5			4·65	11·65	12·2	14·35	17·15	22·35	23·5	26·55	15	16	2+16	2+14	158	♂ v	0+32	55
346	1·32			4·15	10·3	11·15	12·85	15·6	20·35	21·4	24·0	14	16	3+16	2+15	105	♂ iv–v	1+33	57
347	1·5			4·5	11·1	11·4	13·5	16·5	21·35	22·5	25·1	16	17	2+17	2+16	115	♂ iii–vi	1+33	56
348	1·38			4·32	10·75	11·15	13·3	16·1	20·95	22·05	24·7	14	16	2+16	2+15	114	♂ iv–v	†1+32	56
349	1·35			4·3	10·2	11·0	12·75	15·45	20·05	21·1	23·5	14	17	2+17	2+16	100	♂ iv–vi	2+32	56
350	1·33			4·15	10·1	10·65	12·5	15·35	19·9	21·1	23·45	14	16	3+15	3+15	103	♂ v	0+34	56
351	1·34			4·45	10·8	11·95	13·4	16·45	21·65	22·8	25·35	15	16	2+16	2+16	137	♂ v–vi	†0+34*	56

352	1·42		4·4	10·6	11·1	13·3	16·05	20·9	22·0	24·65	15	16	2+17	2+15	117	♂ v	2+31* 55
353	1·38		4·25	10·8	11·75	13·55	16·7	21·75	22·9	25·35	14	17	2+15	2+15	128	♂ v–vi	2+33 56
354	1·5		4·95	12·2	13·4	15·2	18·55	23·8	25·0	28·15	13	16	2+17	2+14	160	♀ v	1+31 55
355	1·35		4·3	10·6	11·35	13·4	16·25	20·95	22·1	24·75	16	17	2+17	2+15	126	♀ iv–v	1+30 55
356	1·43		4·6	11·05	11·7	13·6	16·45	21·4	22·65	25·15	14	17	2+17	2+17	113	♂ iv–vi	0+33 56
357	1·42		4·4	10·3	11·15	12·8	15·65	20·35	21·55	23·9	15	16	3+16	3+14	98	♀ iv	1+32 56
358	1·46		4·45	10·8	11·5	13·45	16·3	20·8	21·85	24·2	15	17	2+17	2+16	109	♀ iv	1+31 56
359	1·34		4·2	9·75	10·75	12·25	14·8	19·6	20·8	22·9	14	17	2+16	3+14	88	♂ iii–vi	†0+33 56
360	1·53		4·75	11·3	12·4	13·9	19·85	21·85	22·95	25·5	14	17	2+17	2+15	116	♂ iii	1+32 56
361	1·27		3·95	9·6	10·25	12·0	14·25	18·83	19·8	22·15	15	16	2+16	2+15	77	♀ iv	1+33 56
362	1·55		4·85	11·95	12·6	14·8	17·65	22·75	24·0	26·65	14	16	2+17	2+16	147	♂ iv–vi	1+32 56
363	1·3		4·2	10·35	11·05	12·75	15·4	19·95	21·05	23·45	16	16	3+16	3+14	84	♂ iii–iv	0+32 56
364	1·35		4·3	10·8	11·5	13·5	16·35	21·15	22·25	24·85	15	16	2+17	2+15	108	♀ iv–v	0+34 56
365	1·34		4·0	9·65	10·15	11·9	14·65	18·95	20·0	22·45	15	17	2+16	2+14	86	♀ ii–iii	†0+33 56
366	1·5		4·8	11·65	12·7	14·5	17·7	22·7	23·9	26·7	14	17	2+17	2+16	156	♀ v	2+31 56
367	1·33		4·2	9·8	11·1	12·5	15·0	19·7	20·6	22·6*	14	15	2+17	2+14	90	♂ iv–vi	2+31 56
368	1·45		4·35	9·95	10·75	12·2	15·1	19·5	20·55	22·8	15	17	2+15	2+15	88	♂ iii–iv	3+31 56
369	1·3		4·2	9·9	10·7	12·6	15·45	20·1	21·15	23·8	15	17	2+17	2+16	108	♂ iv–vi	1+32 55
370	1·4		4·53	11·1	12·2	13·75	17·15	22·05	23·2	25·9	16	17	2+17	2+14	131	♂ v	1+32 56
371	1·45		4·73	11·4	12·45	14·0	17·25	22·25	23·45	26·0	15	16	2+17	2+15	117	♀ iii–iv	0+31 56
372	1·46		4·6	11·4	12·4	14·1	17·0	22·1	23·25	25·85	14	17	2+16	3+14	127	♂ iv–v	0+33 55
373	1·3		4·23	10·15	11·0	12·85	15·35	20·45	21·55	24·15	14	17	2+17	2+17	102	♂ iii–iv	1+32 56
374	1·4		4·4	10·7	11·25	13·5	15·85	20·6	21·75	24·15	15	17	2+16	3+14	106	♂ v	1+32 56
375	1·36		4·53	11·05	11·75	13·95	16·55	21·7	22·85	25·15	15	16	2+17	3+16	120	♂ v	1+33 56
376	1·42		4·4	10·65	11·35	13·35	15·7	20·3	21·5	24·0	15	17	2+17	2+17	112	♀ iv–v	2+30 55
377	1·43		4·6	11·75	12·5	14·5	17·4	22·3	23·45	26·15	15	16	2+15	2+15	145	♀ iv–v	0+32 55
378	1·4		4·66	11·45	12·55	13·95	17·35	22·6	23·8	26·55	15	17	3+15	2+14	141	♀ v	0+33 56
379	1·3		4·16	10·05	10·8	12·35	15·0	19·35	25·0	22·75	15	16	3+16	2+15	95	♂ iv–vi	1+33 57
380	1·4		4·3	10·7	11·4	13·25	16·05	21·0	22·1	24·6	14	17	2+16	2+15	112	♂ iv–vi	1+32 55
381	1·32		4·16	10·05	10·55	12·3	14·8	19·3	20·3	22·6	15	17	2+15	2+14	85	♂ iv	2+32 56
382	1·4		4·3	10·45	11·45	13·15	16·05	20·7	21·8	24·15	15	18	2+17	3+15	106	♀ iii–iv	0+32 56
383	1·46		4·6	11·45	12·05	13·9	17·0	21·8	22·95	25·45	15	16	2+17	2+17	113	♂ iv	1+31 56
384	1·35		4·06	9·8	10·9	12·1	15·0	19·55	20·7	23·1	14	17	2+16	2+15	87	♂ iv	0+33 56
385	1·37		4·45	10·55	11·4	13·2	15·8	20·65	21·75	24·2	15	17	2+18	2+16	104	♂ v	1+32 56
386	1·4		4·33	10·05	10·9	12·6	15·3	20·0	21·05	23·5	15	17	2+16	2+15	91	♀ iii–iv	1+32 56
387	1·47		4·55	11·25	11·8	13·8	16·5	21·7	22·9	25·65	14	17	2+16	2+16	136	♀ v	1+32 56
388	1·53		4·62	12·15	12·7	14·75	17·9	22·85	24·1	26·8	15	16	3+16	2+15	138	♂ v	0+32 56
389	1·44		4·4	10·6	11·45	13·2	15·85	20·75	21·85	24·3	13	17	2+16	2+16	110	♀ iv–v	0+32 56
390	1·34		4·1	10·35	11·0	13·1	15·95	20·9	22·05	24·4	15	16	2+17	2+16	124	♂ v	1+32 56
391	1·4		4·4	10·9	12·3	13·8	17·35	22·15	23·3	25·9	15	16	2+16	2+16	147	♂ v–vi	0+32 56
392	1·3		4·1	9·95	10·4	12·45	14·5	19·2	20·35	22·75	14	15	2+17	2+15	90	♂ v–vi	1+32 55
393	1·64		4·9	12·3	12·9	15·25	18·3	23·3	24·55	27·3	16	17	3+17	3+15	164	♂ v	1+32 57

No. of fish.	1	1*a*	1*b*	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
394	1·4			4·8	11·7	12·7	14·4	17·65	22·9	24·0	26·9	13	17	2+17	3+15	131	♂ v	0+33	56
395	1·53			4·85	12·15	12·9	15·15	17·95	23·2	24·4	27·05	14	17	2+17	3+15	162	♂ v	2+32	56
396	1·4			4·45	11·0	11·8	13·45	16·9	21·7	22·85	25·15	16	16	2+17	2+14	113	♀ iv–v	2+32	57
397	1·67			4·9	12·05	12·6	14·8	18·15	23·35	24·5	27·4	15	17	2+16	2+15	163	♀ v	1+32	56
398	1·5			4·74	11·8	12·6	13·7	18·15	23·1	24·3	27·25	Scales fused. 2+(1+1)+12	17	2+17	2+15	173	♀ v	1+32	56
399	1·5			4·8	11·5	12·3	14·05	17·4	22·45	23·65	26·3	14	17	3+15	2+16	161	♂ v–vi	1+33	57
400	1·7			5·0	12·5	13·25	15·5	18·8	24·1	25·3	28·25	15	18	2+18	2+16	177	♂ v	1+32	56
401	1·44			4·4	10·5	11·65	13·25	16·05	20·6	21·7	24·0	13	18	3+17	2+15	102	♂ iv	1+31	*55
402	1·33			4·2	10·2	11·2	12·75	15·55	20·25	21·3	23·75	14	17	2+17	2+15	108	♀ vi	†0+33	56
403	1·33			4·17	10·2	11·2	12·8	15·8	20·65	21·75	24·25	15	17	2+17	3+15	108	♂ iv	1+33	56
404	1·5			4·5	11·0	11·5	13·6	16·4	21·4	22·6	25·3	15	17	3+17	3+16	118	♂ v–vi	1+32	56
405	1·4			4·36	10·3	11·05	12·9	15·5	20·25	21·3	23·6	15	17	2+17	2+16	107	♀ v	1+30	56
406	1·6			4·85	11·8	12·5	14·65	17·6	22·8	23·9	26·45	15	17	2+17	2+16	160	♂ v	†0+33	56
407	1·47			4·53	11·7	12·6	14·4	17·55	22·55	23·65	26·3	15	17	2+16	2+15	140	♀ iv–v	2+31	56
408	1·5			4·6	11·4	12·3	14·3	17·0	22·35	23·5	26·2	14	17	2+17	2+15	140	♂ v–vi	1+32	56
409	1·5			4·75	11·9	12·1	14·75	17·2	22·7	24·0	26·75	15	16	2+17	2+16	153	♂ v	2+32	56
410	1·4			4·4	11·2	12·2	14·05	17·15	22·3	23·4	26·15	14	16	2+17	2+16	141	♂ iv–v	1+32	56
411	1·44			4·45	10·6	11·4	13·45	16·45	21·25	22·4	24·9	16	16	3+16	2+14	110	♂ iv	2+32	56
412	1·8			5·35	12·3	13·35	15·5	18·95	24·65	25·95	29·1	14	17	2+17	2+16	193	♀ v	1+33	56
413	1·5			4·6	11·8	12·3	14·85	17·85	23·1	24·4	27·1	16	17	2+18	2+16	167	♀ v	1+32	56
414	1·45			4·54	11·55	12·3	14·3	17·3	21·3	23·55	26·4	15	17	2+16	2+14	155	♂ v	0+33	56
415	1·75			5·38	13·5	14·65	16·95	20·25	25·7	27·1	30·15	15	17	3+17	2+16	213	♀ v	1+31	55
416	1·6			4·9	12·2	13·2	15·15	18·35	23·35	24·65	27·6	15	16	3+16	2+15	169	♂ v	1+32*	56
417	1·5			4·6	11·1	11·75	13·7	16·5	21·6	22·7	25·3	14	17	2+16	2+16	113	♀ vi–iii	2+32	56
418	1·6			4·8	11·65	12·5	14·5	17·75	22·5	23·7	26·3	15	16	3+17	2+15	151	♂ v	0+32	56
419	1·46			4·55	11·7	12·5	14·35	17·45	22·45	23·65	26·3	15	17	3+16	2+15	132	♂ iv–v	1+32	56
420	1·44			4·55	11·45	12·6	14·4	17·6	22·7	23·95	26·45	15	16	3+17	3+14	133	♀ vi	2+31	56
421	1·7			5·2	12·25	12·9	15·25	18·55	23·7	25·0	28·0	15	17	3+16	2+14	185	♂ v	2+33	56
422	1·5			4·5	10·6	11·7	13·1	16·25	20·85	22·05	24·55	15	17	2+16	2+16	105	♂ v	†0+32	55
423	1·3			4·15	10·25	10·95	12·85	15·5	20·15	22·2	23·65	15	16	2+18	2+15	95	♂ iv–v	2+30	55
424	1·6			5·0	11·95	12·9	14·9	18·2	23·3	24·55	27·25	14	18	3+17	2+16	163	♂ v	1+32	56
425	1·8			5·33	12·5	13·8	15·55	18·7	24·1	25·5	28·25	14	14	3+17	3+15	175	♀ v	2+31	56
426	1·4			4·37	10·25	11·5	12·8	15·9	20·9	21·95	24·55	15	17	2+17	2+15	115	♀ iii–iv	2+33	57
427	1·5			4·75	12·45	13·0	15·4	18·8	24·4	25·55	28·25	16	18	3+17	2+16	179	♂ v	2+33*	58
428	1·6			4·86	11·9	13·1	14·85	17·8	22·8	24·1	26·9	15	17	3+17	2+16	138	♂ iv	1+31	55
429	1·65			5·0	12·3	13·1	15·3	18·7	24·1	25·3	28·25	15	17	2+16	2+15	191	♂ v	1+32	56
430	1·5			4·65	11·2	11·9	14·2	16·9	22·1	23·3	26·1	14	17	2+17	2+17	153	♂ v	0+32	56
431	1·24			3·9	10·0	10·75	12·3	15·2	19·7	20·7	23·1	15	17	2+17	3+15	102	♂ v	0+33	56
432	1·36			4·36	10·8	11·8	13·65	16·4	21·3	22·5	25·15	15	17	2+17	2+17	128	♀ iv–v	1+33	56

433	1·36	4·5	10·6	11·6	13·4	16·45	21·25	22·35	25·05	14	16	2+17	2+15	110	♂ iv	1+31	55
434	1·7	5·3	12·8	13·3	15·85	18·7	24·1	25·35	28·25	15	17	3+17	1+16	156	♀ vi–iv	3+30	55
435	1·65	4·95	11·75	13·1	14·85	18·15	23·5	24·75	27·85	15	17	2+18	2+17	185	♀ v	1+32	*56
436	1·48	4·5	11·2	11·85	13·7	16·9	22·1	23·35	25·9	15	16	2+17	2+15	132	♂ v	1+31	56
437	1·54	4·9	12·05	13·15	15·05	18·4	24·05	25·2	27·95	5+000+7	17	3+16	2+15	161	♂ v	0+32	56
438	1·45	4·5	10·8	11·55	13·5	16·3	21·6	22·7	25·35	15	16	3+16	3+16	109	♀ vi–iv	1+32	56
439	1·34	4·25	10·3	11·25	12·95	15·45	20·2	21·3	23·6	14	17	2+17	3+15	99	♂ iv	†0+32	56
440	1·45	4·6	11·25	12·1	14·0	16·95	22·2	23·5	26·05	15	18	2+17	2+16	152	♀ iv–v	1+32	57
441	1·47	4·63	11·15	12·0	14·05	16·9	22·3	23·4	26·1	15	17	3+17	2+16	131	♂ iv–v	2+33	57
442	1·6	4·95	11·9	12·95	14·85	17·7	23·25	24·55	27·2	14	18	2+17	3+16	161	♀ v	0+33	56
443	1·36	4·44	11·0	11·45	13·75	16·5	21·8	23·0	25·55	15	17	2+17	2+17	140	♂ v	2+32	56
444	1·35	4·38	10·5	11·4	13·15	16·2	20·95	22·05	24·65	16	17	2+18	2+17	123	♀ iv–v	1+33	56
445	1·4	4·4	10·1	10·85	12·35	15·2	19·8	20·75	23·2	15	17	3+16	2+15	103	♂ v–vi	1+32	55
446	1·4	4·36	10·75	11·2	13·5	15·9	21·0	22·2	24·7	15	17	2+16	2+16	119	♀ iv–v	1+33	56
447	1·5	4·6	11·15	12·0	13·85	16·95	21·85	23·0	25·35	15	15	2+16	3+15	148	♀ v	1+31	55
448	1·35	4·25	10·5	10·95	13·1	15·75	20·4	21·5	24·05	15	16	3+17	2+16	100	♂ iv	2+32	56
449	1·4	4·43	10·65	10·5	13·0	15·65	20·4	21·5	23·85	16	17	2+17	2+16	105	♂ iv–vi	1+32	56
450	1·52	4·54	11·6	12·35	14·45	17·5	22·6	23·8	26·3	15	17	2+17	3+15	157	♀ v	0+33	56
451	1·38	4·43	10·9	13·55	11·9	16·25	21·4	22·55	25·15	15	16	3+16	2+16	121	♀ v	1+32	56
452	1·4	4·33	10·3	11·1	13·1	15·6	20·65	21·8	24·4	14	17	3+16	2+16	118	♂ v	2+32	56
453	1·6	4·98	12·95	13·7	15·9	19·3	24·6	26·05	28·85	15	17	2+15	3+15	194	♀ v	0+32*	55
454	1·53	4·65	10·6	11·05	13·2	15·95	20·95	22·15	24·8	13	16	3+17	2+17	113	♂ v	0+32	55
455	1·35	4·3	11·0	11·3	13·5	16·35	21·35	22·45	24·95	15	17	2+17	3+15	118	♀ iv–v	1+32	56
456	1·5	4·65	11·4	12·45	14·0	17·1	22·35	23·5	26·25	14	17	3+15	2+16	134	♀ v	2+32	57
457	1·5	4·5	11·0	11·65	13·7	16·25	21·4	22·5	25·15	15	17	2+17	2+16	126	♀ iv–v	1+32	56
458	1·47	4·55	11·35	12·2	14·0	17·25	22·05	23·3	26·0	14	16	2+15	2+13	155	♂ v	2+32	56
459	1·74	5·05	12·7	13·65	15·9	19·2	24·5	25·8	28·55	15	17	2+17	2+16	171	♀ iv–v	0+34	57
460	1·4	4·55	11·6	12·1	14·05	17·15	22·1	23·25	25·75	15	16	2+16	2+15	154	♂ v	1+32	56
461	1·43	4·6	11·1	11·9	13·75	16·4	21·5	22·6	25·05	14	17	2+17	2+16	117	♂ v–vi	1+32	56
462	1·48	4·4	10·95	11·55	13·8	16·5	21·7	22·95	25·5	15	16	3+17	2+16	126	♀ v	1+0*+32	56
463	1·6	4·86	12·0	12·7	14·95	17·95	22·9	24·25	26·7	14	16	2+17	2+14	164	♂ v	1+32	56
464	1·6	4·9	11·8	12·65	14·6	17·65	22·85	24·0	26·6	14	17	3+16	1+16	134	♂ v	1+31	55
465	1·5	4·5	10·55	11·4	13·15	15·9	20·7	21·8	24·2	15	16	2+17	2+16	108	♀ iv–v	1+33	57
466	1·4	4·4	11·15	11·9	14·0	16·8	21·95	23·1	25·6	15	18	3+17	2+15	133	♀ ii–iii	2+31	56
467	1·38	4·38	10·75	11·45	13·25	15·8	21·0	22·15	24·6	14	17	2+17	1+15	100	♀ vi–iii	1+33	56
468	1·4	4·25	10·25	10·75	12·45	15·05	19·7	20·75	23·3	15	18	2+17	2+16	98	♂ v	0+33	57
469	1·43	4·42	10·6	11·1	13·2	16·05	20·85	22·0	24·4	14	17	3+17	2+15	98	♀ vii	1+33	57
470	1·56	4·72	11·65	12·65	14·7	17·95	22·85	24·0	26·7	15	(17 l.) 11 r. (abnrm.)	2+18	1+15	148	♀ v	1+32	56
471	1·4	4·38	10·5	10·95	13·2	15·4	20·5	21·65	24·05	14	16	3+17	1+15	98	♂ iii–iv	0+32	56
472	1·3	4·13	10·1	10·55	12·35	14·85	19·35	20·35	22·7	14	17	3+17	2+16	93	♂ v	1+32	56
473	1·46	4·45	10·65	11·1	13·35	15·6	20·9	22·0	24·5	14	16	3+17	1+15	111	♂ iv–v	1+33	56

No. of fish.	1	1a	1b	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
474	1·3			4·3	10·15	10·55	12·75	14·9	19·6	20·8	23·3	14	16	2 + 18	2 + 16	103	♀ iv	0 + 32	55
475	1·5			4·63	11·5	12·6	14·25	17·85	22·6	23·85	26·6	15	16	3 + 16	2 + 14	159	♀ v	1 + 32	56
476	1·35			4·25	10·65	11·45	13·25	16·0	21·0	22·1	24·5	14	16	3 + 17	2 + 15	116	♂ v–vi	0 + 32	56
477	1·7			5·1	12·65	13·7	15·55	19·1	24·6	25·8	28·7	14	17	3 + 16	2 + 15	155	♀ iv	1 + 32	56
478	1·5			4·68	11·3	12·2	13·95	17·45	22·05	23·3	26·15	16	16	3 + 16	2 + 14	141	♂ v–vi	1 + 31	55
479	1·3			4·0	9·75	11·0	12·45	15·1	19·75	20·85	23·05	15	17	2 + 17	2 + 15	94	♀ ii iii	2 + 31	56
480	1·6			4·9	11·6	12·2	14·4	17·05	22·15	23·3	26·1	15	17	3 + 17	2 + 14	147	♀ v	2 + 31	56
481	1·4			4·32	10·3	10·8	12·45	15·5	19·6	20·7	23·15	14	17	2 + 17	2 + 14	99	♀ ii–iii	0 + 33	56
482	1·28			3·9	9·55	9·85	11·85	13·95	18·35	19·5	21·7	16	17	3 + 16	2 + 15	84	♂ v	1 + 31	55
483	1·53			4·9	12·35	12·9	15·6	18·65	23·9	25·3	28·2	14	18	3 + 18	2 + 16	185	♀ v	1 + 33	56
484	1·6			4·7	11·45	12·15	14·2	17·4	22·3	23·5	26·05	15	16	3 + 16	1 + 16	146	♀ v	1 + 34	57
485	1·38			4·35	10·5	11·15	13·2	15·6	20·75	21·8	24·45	13	17	3 + 18	2 + 16	102	♀ iii–iv	0 + 33	57
486	1·45			4·44	10·7	11·6	13·55	16·7	21·4	22·7	25·25	15	17	2 + 18	2 + 15	137	♂ v	1 + 30	55
487	1·5			4·42	10·8	11·5	13·5	16·7	21·3	22·5	25·1	15	17	2 + 17	1 + 14	125	♂ iv	0 + 32	56
488	1·7			5·14	12·36	13·3	15·7	18·55	23·8	25·1	28·0	16	17	3 + 18	2 + 16	190	♂ v	1 + 33	56
489	1·56			4·62	11·35	11·85	14·1	16·65	21·9	23·0	25·6	15	17	3 + 17	2 + 15	126	♂ iv–v	2 + 32	56
490	1·76			4·96	12·4	13·4	15·5	18·55	23·95	25·3	28·0	13	18	2 + 17	2 + 15	187	♀ v	0 + 32	55
491	1·36			4·2	10·25	11·1	13·0	15·75	20·6	21·75	24·15	1+0+12	16	2 + 17	2 + 15	103	♂ v	1 + 32	56
492	1·6			4·92	12·0	12·15	14·7	17·6	22·55	23·75	26·3	15	17	3 + 16	1 + 17	159	♂ v	2 + 31	56
493	1·5			4·36	10·75	11·6	13·45	16·45	21·35	22·5	25·2	16	17	3 + 16	2 + 15	133	♀ v	0 + 32	56
494	1·5			4·5	11·0	12·0	13·55	16·4	21·45	22·65	25·3	15	15	3 + 16	2 + 14	127	♀ iv–v	1 + 31	56
495	1·6			5·24	12·75	13·9	15·95	18·8	24·6	25·95	28·65	14	16	3 + 17	2 + 15	184	♂ v	2 + 30	55
496	1·7			5·03	12·3	13·75	15·25	18·4	23·7	25·05	27·8	14	15	3 + 15	2 + 15	163	♀ v	0 + 33	56
497	1·76			5·42	13·1	13·6	16·05	18·8	24·35	25·7	28·65	15	17	2 + 17	2 + 16	191	♂ v	1 + 32	56
498	1·7			5·0	11·8	12·8	14·5	17·7	22·8	24·15	27·1	15	18	2 + 16	1 + 15	154	♀ v	1 + 32	55
499	1·4			4·5	10·85	12·0	13·9	16·6	21·85	23·0	25·7	14	17	2 + 18	2 + 15	133	♂ iv–v	0 + 32	56
500	1·58			4·85	11·8	12·8	14·7	18·1	22·75	24·0	26·65	16	17	2 + 17	2 + 14	158	♂ v	0 + 33	55
501	1·58			4·72	11·95	13·0	14·9	17·9	23·3	24·55	27·45	15	18	2 + 17	2 + 16	175	♀ v	2 + 32	57
502	1·58			4·75	11·1	12·05	13·9	16·8	21·75	22·9	25·6	15	16	3 + 17	2 + 16	131	♂ v	2 + 31	56
503	1·6			4·62	11·6	12·1	14·2	17·35	22·35	23·6	26·25	14	17	3 + 16	3 + 15	136	♂ v–vi	0 + 32	55
504	1·42			4·3	10·85	11·65	13·75	16·4	21·65	22·75	25·2	15	17	2 + 17	2 + 15	121	iv–v	0 + 32	56
505	1·6			4·65	11·3	12·0	14·15	16·8	22·5	23·6	26·25	15	17	3 + 17	2 + 17	136	v	0 + 32	56
506	1·36			4·3	10·65	11·3	13·7	16·4	21·15	22·3	24·95	15	16	3 + 18	2 + 15	137	♂ v–vi	1 + 31	55
507	1·65			5·18	12·65	12·4	15·6	18·5	23·65	24·9	27·85	15	17	2 + 16	2 + 14	164	♂ v	1 + 32	55
508	1·45			4·4	10·15	10·85	12·7	15·0	19·95	21·05	23·5	14	17	2 + 16	2 + 15	109	♂ v	1 + 32	56
509	1·6			4·7	10·9	11·55	13·65	16·5	21·3	22·5	25·1	15	16	3 + 17	2 + 14	117	♂ iv–vi	0 + 32	56
510	1·48			4·55	10·8	11·55	13·2	16·25	21·0	22·1	24·7	16	16	2 + 15	2 + 15	111	♂ iii iv	0 + 31	56
511	1·3			4·2	10·35	11·1	12·8	15·65	20·3	21·4	23·9	14	17	3 + 16	2 + 15	113	♂ v	1 + 32	56
512	1·45			4·38	10·4	11·1	12·7	15·7	20·4	21·5	24·0	14	17	3 + 16	2 + 14	106	♂ v	3 + 30	55

513	1·6	5·0	12·35	13·25	15·35	18·1	24·1	25·3	28·15	15	16	2 + 17	2 + 15	177	♂ v	2 + 31	56
514	1·6	4·65	11·8	12·75	14·55	17·85	22·9	24·15	26·8	15	17	2 + 16	2 + 15	168	♀ v	1 + 31	55
515	1·56	4·85	12·0	12·5	14·6	17·95	22·95	24·15	26·9	15	17	2 + 16	2 + 14	157	♀ iv–v	2 + 31	56
516	1·53	4·5	10·65	11·45	13·2	16·35	20·95	22·05	24·5	16	16	3 + 17	2 + 14	124	♂ iv–v	2 + 30	55
517	1·58	4·78	11·7	13·1	14·4	17·7	22·95	24·1	27·05	14	16	2 + 16	2 + 15	159	♀ iv–v	1 + 34	57
518	1·55	4·6	11·4	12·4	13·1	17·55	22·65	23·8	26·6	15	17	3 + 15	2 + 14	138	♀ iv	1 + 31	55
519	1·35	4·46	11·2	11·75	13·9	16·45	21·7	22·9	25·4	14	17	3 + 16	2 + 15	135	♂ iv	0 + 32	55
520	1·52	4·72	11·3	12·25	14·35	17·2	22·65	23·85	26·45	15	17	2 + 17	2 + 16	134	♀ vii	2 + 32	55
521	1·5	4·45	11·15	11·7	13·9	16·65	21·95	23·1	25·85	14	16	2 + 17	2 + 15	133	♀ vi	1 + 32	56
522	1·52	4·8	11·6	12·4	14·4	17·3	22·3	23·55	26·1	14	17	2 + 17	2 + 16	150	[illegible] iv–v	1 + 32	56
523	1·4	4·22	10·5	10·9	12·95	15·2	20·25	21·3	23·8	14	18	2 + 17	2 + 16	105	♂ iv	0 + 33	56
524	1·34	3·9	9·45	10·1	11·8	14·0	18·7	19·75	21·9	15	17	3 + 17	2 + 17	76	♂ iv	1 + 32	56
525	1·48	4·36	10·5	11·4	13·05	16·1	20·85	21·95	24·45	16	17	3 + 17	2 + 15	118	♀ vi	0 + 32	56
526	1·52	4·6	11·15	11·7	13·9	16·35	21·35	22·6	25·15	14	16	3 + 17	2 + 16	122	♂ iv–v	2 + 31	56
527	1·47	4·44	10·7	11·8	13·55	16·5	21·1	22·2	24·7	15	17	3 + 17	2 + 15	125	♀ iv–v	0 + 31	55
528	1·7	5·0	11·8	12·85	14·8	17·9	23·0	24·2	27·0	15	17	2 + 16	3 + 15	154	♂ v	1 + 32	56
529	1·5	4·4	10·8	11·05	12·7	15·45	20·05	21·2	23·75	14	18	2 + 16	2 + 15	109	♀ iv–v	2 + 30*	54
530	1·58	4·65	11·7	12·5	14·6	17·45	22·75	23·95	26·6	15	17	2 + 16	3 + 16	166	♂ v–vi	1 + 32	56
531	1·6	4·88	12·2	13·05	15·1	18·1	23·45	24·8	27·4	14	16	2 + 17	2 + 15	160	♂ v	1 + 31	55
532	1·64	4·97	11·95	12·6	15·1	17·7	22·7	24·0	26·65	15	16	2 + 17	2 + 15	152	♂ iv	3 + 30	56
533	1·42	4·4	10·4	11·3	12·8	15·6	20·25	21·25	23·65	15	16	2 + 16	3 + 15	100	♂ iv–v	1 + 32	56
534	1·36	4·4	10·55	11·4	13·0	15·5	20·4	21·5	23·9	15	17	2 + 17	2 + 16	104	♂ v	†0 + 32	56
535	1·5	4·25	10·2	10·95	12·9	15·3	20·1	21·2	23·5	15	17	2 + 18	2 + 16	111	♂ iv–v	2 + 32	56
536	1·44	4·47	10·95	11·5	13·5	16·45	21·45	22·5	25·0	15	17	2 + 16	2 + 15	139	♂ v–vi	1 + 33	56
537	1·4	4·3	10·55	11·7	13·15	16·0	20·9	22·05	24·5	15	17	3 + 16	2 + 15	115	♂ v	0 + 33	56
538	1·53	4·72	11·95	12·6	14·55	17·55	22·9	24·1	26·95	14	17	2 + 17	2 + 16	140	♀ vi–iii	2 + 32	57
539	1·5	4·8	11·95	12·4	14·7	17·8	22·85	24·1	26·8	16	17	2 + 17	2 + 15	163	♀ vi	1 + 32	56
540	1·5	4·65	11·7	12·3	14·25	17·3	22·4	23·7	26·35	15	17	2 + 16	2 + 15	143	♂ v	0 + 32	55
541	1·3	4·06	10·2	11·05	11·8	15·5	20·45	21·55	23·95	15	17	2 + 17	2 + 17	103	♀ v	†0 + 32	56
542	1·46	4·3	10·55	11·35	13·15	15·7	21·1	22·2	24·8	15	16	2 + 17	2 + 16	126	♀ v	1 + 32	57
543	1·5	4·64	10·95	11·85	13·65	16·55	21·6	22·75	25·3	13	17	1 + 17	2 + 16	136	♀ iv–v	0 + 32	55
544	1·6	4·96	12·85	13·85	15·8	19·0	24·5	25·7	28·35	16	17	2 + 16	2 + 15	199	♂ v	1 + 32	56
545	1·68	5·0	12·6	13·3	15·4	18·45	23·9	25·25	28·15	15	17	3 + 15	1 + 16	174	♂ v	0 + 32	55
546	1·4	4·3	10·25	10·7	13·0	15·1	20·0	21·1	23·6	14	17	3 + 18	3 + 16	115	♂ v	0 + 31*	55
547	1·44	4·5	11·1	12·05	13·85	16·9	21·8	23·0	25·6	14	17	2 + 17	2 + 16	136	♂ v	1 + 33	56
548	1·43	4·15	9·95	10·7	12·3	14·9	19·5	20·55	23·05	16	16	2 + 17	2 + 16	104	♂ v–vi	1 + 32	56
549	1·5	4·45	11·35	12·05	14·2	17·1	22·1	23·2	25·8	16	17	3 + 15	2 + 15	150	♂ v	0 + 33	56
550	1·6	4·8	11·8	12·65	14·6	18·15	23·4	24·6	27·3	15	17	3 + 16	3 + 15	173	♀ v	1 + 33	57

IV. Herring Race Investigations.

HAUL.

Position . . Start Pt. E.N.E. about 8 miles to N.N.E. about 3 miles.
Date . . Jan. 6 15. Landed 10.0 a.m.
Vessel . . "G.M.V.," Lowestoft (Steam drifter).
Net . . Drift-herring.

SAMPLE IV.

Number examined . . 525.
Quantity of fish caught . 56 cran (about 50,500).
Date examined . . Jan. 6/15.
Examined by . . . J. H. Orton and others.

The characters are briefly: Length in centimetres from snout to **(1)** eye, **(2)** operculum edge, **(3)** front of dorsal fin, **(4)** pelvic, **(5)** back of dorsal, **(6)** front of anal, **(7)** root of tail, **(8)** end of mid-caudal, **(9)** end of longest caudal ray. Number of **(11)** keeled scales (pelvics to anus), **(12)** rays in pectoral, **(13)** rays in dorsal, **(14)** rays in anal, **(15)** weight in grams, **(16)** sex and maturity, **(17)** vertebræ with hæmal arch, **(18)** total vertebræ. * For explanation of signs see Appendix to Tables.

No. of fish.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
551	1·7	5·26	12·65	14·05	15·8	19·0	24·6	25·9	28·8	15	17	3+16	3+14	157	♂ iv–v	2+31	55
552	1·55	4·85	11·85	12·5	14·5	17·85	22·7	24·0	26·5	15	16	2+16	3+15	156	♀ vi	0+33*	56
553	1·7	5·2	12·45	13·45	15·6	19·45	24·5	25·9	28·75	16	16	3+16	3+14	140	♀ vii	2+32	56
554	1·6	4·8	11·8	12·55	14·6	17·65	22·75	24·0	26·9	15	16	3+16	1+3+13	154	♀ vi	2+32	55
555	1·5	4·85	12·1	13·0	15·1	18·15	23·65	24·85	27·7	16	17	3+17	3+15	172	♀ iv	1+33	56
556	1·8	5·4	12·95	13·7	16·1	18·85	24·6	26·0	28·75	15	Fused? 12+(1+1)+2	2+17	1+3+14	171	♀ vi	1+32	56
557	1·4	4·4	10·8	11·5	13·45	16·05	20·9	22·1	24·45	15	17	3+17	3+15	117	♂ iv–v	2+31	55
558	1·5	4·85	12·05	12·65	14·9	18·0	23·1	24·2	26·9	17	18	3+16	3+14	149	♂ iv–v	2+33	57
559	1·6	4·85	11·3	12·6	14·35	17·6	22·3	23·5	26·3	14	17	3+16	3+14	161	♀ vi	†0+32	55
560	1·57	4·8	12·1	12·7	14·8	18·15	23·4	24·7	27·2	14	16	3+16	4+15	167	♂ v–vi	1+33	57
561	1·46	4·6	11·5	12·15	14·4	17·1	22·2	23·5	26·15	14	17	3+17	3+14	162	♂ v–vi	2+31	56
562	1·47	4·65	11·4	12·2	14·3	17·3	22·4	23·65	26·25*	15	17	3+16	3+14	131	♂ v–vi	0+34	57
563	1·28	4·35	10·9	11·6	13·6	16·4	21·3	22·45	25·05	15	17	3+15	3+13	129	♀ vi	†1+32	56
564	1·5	4·9	12·5	13·2	15·55	18·5	23·45	24·65	27·5	14	17	3+16	3+13	145	♂ vii	1+31	56
565	1·38	4·4	11·15	11·9	13·65	16·4	21·3	22·5	25·05	14	18	3+16	3+15	121	♂ vi–iii	1+31	55
566	1·5	4·45	10·75	11·4	13·34	15·95	20·65	21·8	24·25	13	16	3+16	3+15*	118	♂ v	†0+33	56
567	1·5	4·88	11·75	12·8	14·6	18·0	22·95	24·2	26·65	15	17	3+17	3+14	153	♂ vi–iv	1+32	56
568	1·65	5·0	12·25	13·2	15·25	18·2	23·45	24·7	27·6	15	16	3+16	3+15	175	♂ v	2+31	55
569	1·5	4·7	11·1	11·95	13·8	16·5	21·55	22·7	25·5	15	17	3+16	3+14	137	♂ vi	2+31	55
570	1·45	4·6	11·36	12·6	13·95	17·25	22·3	23·5	26·2	14	17	3+15	3+14	139	♂ iv–v	†2+31	56
571	1·5	4·63	11·4	12·5	14·25	17·55	22·75	24·05	26·45	15	16	3+17	1+3+14	146	♂ v–vi	1+33	57
572	1·5	4·7	11·4	12·6	14·2	17·1	22·1	23·25	26·05	15	17	3+16	3+15	150	♂ vi	1+32	56
573	1·48	4·6	11·1	12·0	13·65	16·75	21·6	22·8	25·4	15	17	3+15	1+3+14	113	♂ vi–iii	1+32	(21+‡?+2) =55
574	1·5	4·7	12·2	12·8	14·9	18·0	23·55	24·8	27·5	14	17	3+15	3+13	167	♂ v–vi	0+33	56
575	1·65	5·1	12·5	13·45	15·35	18·6	23·5	24·8	27·55	14	17	3+16	4+13	141	♂ vii	1+31	55
576	1·54	4·85	11·9	12·4	14·55	17·2	22·35	23·6	26·3	14	17	3+15	3+15	129	♀ vii	†0+32	55

‡ Some may be missing here. Skeleton broken.

577	1·46	4·7	11·8	12·6	14·3	17·65	22·7	24·1	26·8	15	17	3+14	3+14	152	♀ v–vi	2+32	56
578	1·53	4·75	11·55	12·3	14·1	17·25	22·1	23·35	25·95	13	17	3+16	4+13	127	♀ vi–iii	3+31	55
579	1·7	5·1	12·35	13·4	15·6	18·55	24·0	25·4	28·15	14	18	3+16	3+13	192	♀ vi	2+31	55
580	1·5	4·75	12·45	13·25	15·4	18·8	23·9	25·2	27·8	17	17	3+16	3+14	190	♀ vi	2+32*	56
581	1·5	4·6	11·35	12·05	14·3	16·95	22·3	23·5	26·2	15	16	3+17	4+15	128	♀ iii	†0+33	56
582	1·33	4·38	10·95	11·55	13·85	16·8	21·5	22·8	25·05	15	17	3+17	4+13	131	♂ v–vi	1+32*	55
583	1·5	4·65	11·55	12·6	14·4	17·45	22·85	24·0	26·7	14	17	3+16	3+16	137	♂ vi–iii	1+32	55
584	1·74	5·2	12·5	13·3	15·45	18·7	23·95	25·4	28·05	15	18	3+16	3+14	169	♂ v–vi	2+31	55
585	1·45	4·6	11·35	12·2	14·15	17·35	22·3	23·45	26·05	16	16	2+16	3+13	151	♂ v–vi	2+32	56
586	1·56	4·75	11·75	12·9	14·5	18·45	23·4	24·65	27·3	15	17	2+16	3+14	167	♀ vi	1+32	56
587	1·44	4·6	11·3	12·25	14·05	17·5	22·45	23·65	26·25	15	Rt. broken, left 17.	3+16	3+14	144	♂ iv–v	2+32	56
588	1·7	5·05	12·3	12·9	15·2	18·3	23·4	24·7	27·3	15	18	3+16	3+14	145	♂ vi–iii	1+33	56*
589	1·78	5·26	12·6	13·1	15·6	18·0	24·3	25·65	28·45	14	17	3+16	4+14	157	♀ vii	1+32	57
590	1·48	4·65	11·85	12·45	14·7	17·45	22·4	23·65	26·3	14	17	3+17	4+14	140	♂ v–vi	†2+32	56
591	1·6	5·0	11·75	12·7	14·85	17·75	22·8	24·05	26·85	14	17	3+16	3+13	166	♀ vi–iv	3+31	55
592	1·5	4·6	11·5	12·3	14·4	16·95	22·15	23·4	26·15	14	16	2+16	3+15	119	♀ vi–iv	2+32	56
593	1·43	4·43	10·95	11·6	13·85	16·3	21·75	22·95	25·4	15	17	3+17	4+15	128	♂ v–vi	0+33	56
594	1·5	4·85	11·8	12·65	14·8	17·35	22·65	23·9	26·5	15	17	2+17	3+14	158	♂ v–vi	1+32	56
595	1·4	4·47	11·15	11·55	13·9	16·65	21·75	23·0	25·3	16	16	4+16	3+14	136	♂ vi	1+33	56
596	1·54	4·7	12·1	12·5	15·05	17·9	23·2	24·4	26·95	16	16	3+17	3+14	170	♀ vi	1+33	56
597	1·78	5·35	12·25	12·9	15·3	18·2	23·95	25·2	28·1	15	17	3+16	3+13	171	♂ v	1+33	56
598	1·48	4·55	11·2	12·1	14·0	16·85	21·95	23·1	25·65	15	17	3+16	3+15	134	♂ iv–vi	†0+34	57
599	1·56	4·9	12·25	13·05	15·5	18·3	23·7	24·9	28·0	15	17	3+17	3+15	151	♀ vii	2+31	56
600	1·5	4·4	10·85	11·6	13·7	16·2	21·2	22·3	24·85	15	17	3+16	4+13	123	♂ vi–iii	1+31	55
601	1·68	5·28	13·3	14·2	16·5	19·65	25·4	26·75	29·6	14	17	3+16	3+14	207	♂ vi	1+32	56
602	1·65	4·9	12·06	13·1	15·1	18·1	23·2	24·4	27·1	15	17	2+16	2+14	180	♀ vi	2+32	56
603	1·6	5·0	12·1	12·6	15·1	17·6	23·3	24·55	27·1	14	17	3+16	4+15	157	♀ iii	2+32	56
604	1·6	5·0	11·8	12·95	14·8	17·95	23·15	24·4	27·35	14	17	3+16	3+16	149	♀ vi–iv	†1+33	56
605	1·38	4·4	11·1	11·85	13·8	16·6	21·75	22·95	25·55	15	16	3+16	3+15	137	♂ v–vi	†0+32	55
606	1·56	4·7	11·3	12·4	14·2	17·65	22·7	24·0	26·7	16	16	3+16	3+15	160	♀ vi	1+32	56
607	1·52	4·65	11·5	12·5	14·55	17·6	22·65	23·9	26·4	16	16	3+16	4+13	157	♀ vi	1+32	55
608	1·68	5·14	12·3	13·00	15·55	18·55	24·0	25·3	28·2	15	17	3+16	3+14	176	♀ vi–iii	2+31	55
609	1·6	4·9	11·8	12·4	14·65	17·55	23·0	24·2	26·7	15	17	3+16	3+15	128	♂ vi–iii	†0+34	57
610	1·4	4·6	11·6	12·3	14·3	17·3	22·3	23·45	26·1	14	16	3+16	3+15	137	♀ vi–iv	†0+33	56
611	1·44	4·6	11·15	11·7	13·85	16·45	21·65	22·8	25·3	15	17	3+17	3+14	106	♂ iv–vi	2+32	56
612	1·48	4·45	10·65	10·95	13·35	15·65	20·55	21·65	24·15	15	16	3+17	3+14	117	♂ vi	0+33	56
613	1·3	4·15	10·2	10·55	12·7	15·1	19·55	20·6	22·7	15	18	3+16	3+14	101	♂ v–vi	2+32	56
614	1·25	4·2	10·15	10·7	12·85	15·05	19·85	21·0	23·3	16	17	2+17	3+13	108	♀ vi–iii	1+32	56
615	1·4	4·45	11·25	12·2	14·1	17·05	22·35	23·6	26·3	15	18	3+16	4+13	165	♂ vi	1+32	55
616	1·6	5·0	12·4	13·6	15·6	18·95	24·2	25·6	28·45	14	17	3+16	3+15	200	♀ vi	1+31	55
617	1·73	5·3	12·05	12·80	15·35	17·5	23·0	24·3	27·1	15	17	3+17	3+14	159	♀ vi–iii	1+32	56

No. of fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
618	1·47	4·7	11·7	12·7	14·55	17·5	22·6	23·9	26·65	15	17	3+16	4+13	154	♀ vi–iv	†0+33	56
619	1·56	4·9	12·2	12·9	15·05	17·8	23·15	24·35	27·1	14	17	3+16	4+14	188	♀ vi	0+32	57
620	1·64	4·8	12·1	12·6	14·9	17·8	22·85	24·15	26·8	15	17	3+16	4+15	146	♀ vi–iii	2+32	56
621	1·63	4·95	11·45	12·45	14·5	17·3	22·6	23·85	26·45	14	16	3+17	4+13	136	♀ vi–iii	0+33	56
622	1·4	4·6	11·25	12·3	14·2	17·4	22·45	23·8	26·2	15	17	3+17	3+13	160	♂ v–vi	0+32	56
623	1·45	4·55	11·4	12·4	14·2	17·0	22·4	23·6	26·05	14	17	3+15	2+14	143	♂ vi–iv	0+34	56
624	1·65	4·9	11·75	12·35	14·7	17·65	22·7	23·95	26·8	14	17	3+16	3+15	165	♀ vi	0+33	56
625	1·64	4·95	12·3	13·6	15·25	18·9	24·0	25·4	28·15	15	17	3+15	3+12	199	♀ vi	1+33	57
626	1·76	5·43	13·1	14·4	16·5	19·75	25·35	26·8	29·95	15	18	3+16	3+15	187	♂ vi	0+33	56
627	1·6	5·1	12·6	13·3	15·8	18·45	24·25	25·55	28·65	15	17	2+17	3+16	180	♂ vi	0+33	56
628	1·6	5·13	12·4	13·2	15·2	18·65	23·8	25·05	27·35*	16	16	3+15	3+13	136	♂ ii	1+31	55
629	1·43	4·45	10·8	11·7	13·4	16·6	21·4	22·55	25·1	15	19	3+16	3+13	142	♀ vi	1+32	56
630	1·53	4·85	12·0	12·8	14·95	17·7	23·2	24·45	27·2	14	17	3+16	3+14	148	♂ vi–iii	1+31	55
631	1·52	5·0	12·2	12·8	14·95	18·05	22·3	24·6	27·5	14	17	3+16	3+14	175	♂ vi *0	[1+1+30]	55
632	1·6	5·0	12·55	13·00	15·55	18·35	24·15	25·4	27·95	15	18	3+16	3+15	168	♀ vi	0+33	57
633	1·6	4·85	12·45	13·3	15·45	18·6	24·1	25·45	27·7*	14	18	3+15	3+14	171	♂ vi	1+32	56
634	1·5	4·42	11·5	12·4	14·05	17·4	22·4	23·65	26·15	15	17	3+16	3+14	148	♀ iii–iv	1+33	56
635	1·4	4·7	11·3	11·7	14·05	16·75	21·8	23·05	25·65	14	17	3+17	3+13	117	♂ vi–iii	1+32	56
636	1·53	4·9	11·8	12·45	14·9	17·6	22·8	24·05	26·75	14	17	3+17	2+14	140	♂ vi	0+32	55
637	1·5	4·65	11·4	12·6	14·35	17·5	22·4	23·65	26·4	15	17	3+16	2+14	145	♀ vi	2+31	56
638	1·4	4·7	12·3	12·6	15·15	17·75	22·75	23·95	26·5	15	17	3+16	3+14	156	♀ vi	†0+32	56
639	1·55	4·85	11·6	12·85	14·6	17·8	22·8	24·1	26·75	15	16	3+17	3+14	141	♀ vi–iv	1+32	55
640	1·43	4·6	11·8	12·5	14·65	17·75	22·9	24·15	26·8	15	16	3+17	2+14	144	♂ vi	2+32	57
641	1·54	4·9	11·8	12·7	14·65	17·5	22·3	23·6	26·25	15	17	3+15	3+14	138	♀ vi–iii	1+31	55
642	1·43	4·65	11·5	12·25	14·2	17·1	22·0	23·1	25·95	14	16	3+16	3+14	137	♂ vi	1+32	56
643	1·47	4·44	10·9	11·55	13·55	16·0	21·15	22·35	24·85	14	16	3+16	4+14	129	♂ vi	1+33	56
644	1·6	4·9	12·1	12·7	14·75	17·9	23·15	24·35	27·15	15	17	3+16	3+15	148	♂ v–vi	0+32	55
645	1·48	4·6	11·15	11·85	13·9	16·7	21·8	22·9	25·5	16	16	4+16	3+14	127	♀ iii	1+33	57
646	1·55	4·8	12·0	12·7	14·8	17·9	23·15	24·5	27·2	14	18	3+16	3+14	177	♀ vi	1+30	54
647	1·48	4·65	11·55	12·5	14·35	17·5	22·25	23·6	26·35	14	16	3+16	2+13	152	♀ vi	0+32	55
648	1·67	5·37	12·95	13·7	16·05	19·2	24·65	25·95	28·7	17	17	3+16	1+3+14	181	♀ v	2+32	56
649	1·6	4·85	11·9	12·45	14·75	17·6	22·75	24·0	26·7	14	17	3+17	3+15	152	♂ ii	1+32	55
650	1·5	5·0	12·45	13·0	15·4	18·3	23·9	25·15	27·8	14	16	3+17	3+15	170	♂ vi	1+33	57
651	1·6	4·8	11·4	12·2	14·35	17·35	22·5	23·7	26·4	15	17	3+16	3+13	161	♀ vi	1+32	55
652	1·4	4·6	11·7	12·7	14·4	17·7	22·9	24·2	26·8	15	16	3+15	3+14	149	♂ vi–iii	2+32	55
653	1·63	5·05	11·75	12·4	14·7	17·4	22·55	23·8	26·6	15	17	3+17	4+14	135	♂ v	1+32	55
654	1·38	4·35	10·45	11·2	13·1	15·95	20·8	22·0	24·5	15	18	3+17	4+13	114	♀ vi–iii	†2+32	57
655	1·6	4·7	11·6	12·3	14·3	17·35	22·25	23·45	26·1	9+0+0+0+3	17	3+17	3+14	140	♂ vi	2+32	56
656	1·42	4·55	11·45	12·25	14·2	17·2	22·55	23·8	26·2	15	17	3+16	3+15	132	♂ v–vi	1+33	56

657	1·5	4·7	12·0	12·55	14·75	17·5	22·8	24·05	26·7	14	17	3+16	3+15	152	♀ vi	1+32	56
658	1·58	5·0	12·4	12·95	15·35	18·0	23·25	24·45	27·1	14	17	3+16	3+14	150	♂ v	2+31	55
659	1·6	4·7	11·2	12·2	14·05	16·5	21·55	22·8	25·3	14	17	3+17	3+15	136	♀ vi	0+33	56
660	1·5	5·0	12·3	12·8	15·2	18·0	23·4	24·5	27·4	14	17	3+16	1+4+13	155	♂ v–vi	2+32	55
661	1·47	4·7	11·65	12·3	14·6	17·3	22·55	23·8	26·6	14	16	3+16	3+14	160	♂ vi	2+31	55
662	1·45	4·6	11·05	11·85	13·65	16·25	21·2	22·45	25·15	14	16	3+16	3+14	128	♂ v–vi	2+30	54
663	1·55	5·15	12·75	13·25	15·8	18·8	24·15	25·5	28·35	16	17	3+16	3+14	144	♂ ii	2+31	56
664	1·36	4·42	11·1	11·7	13·85	16·55	21·6	22·7	25·2	16	18	3+16	3+16	135	♂ v–vi	0+32	55*
665	1·34	4·36	10·75	11·5	13·2	16·35	21·3	22·4	24·9	15	17	3+15	3+14	125	♂ v–vi	0+33	57
666	1·5	4·9	12·3	12·85	15·15	18·4	23·5	24·75	27·6	16	18	3+15	3+15	164	♂ v–vi	1+33	56
667	1·5	4·6	11·0	11·8	13·65	16·6	21·5	22·55	25·2	15	17	3+16	3+13	118	♂ ii	1+32	56*
668	1·38	4·3	10·75	11·3	13·4	16·0	20·65	21·8	24·4	15	16	3+16	3+14	119	♂ iii	1+31	55
669	1·4	4·5	11·1	11·75	13·95	16·6	22·1	23·3	25·8†	14	18	3+16	3+15	139	♀ vi	1+31	55
670	1·46	4·45	10·9	11·7	13·7	16·75	21·7	22·9	25·4	15	17	3+17	3+16	119	♂ vi	0+32	56
671	1·35	4·5	10·7	11·9	13·65	16·6	21·75	23·0	25·55	15	17	3+16	3+14	128	♀ i–ii	1+32	56
672	1·6	5·05	12·1	13·0	15·1	18·2	23·9	25·2	27·8	1+0+11	17	3+17	3+14	169	♀ iv	1+33	57
673	1·52	4·55	11·55	12·1	14·45	17·35	22·5	23·75	26·45	15	16	3+16	1+3+13	128	♀ vi–iii	1+32	55
674	1·5	4·53	11·55	12·8	14·45	17·9	22·9	24·1	26·8	14	16	3+16	Total 17. Rays broken.	140	♀ vi–iii	0+33	57
675	1·38	4·35	11·0	11·65	13·4	16·3	21·15	22·25	24·85	14	17	3+15	3+15	110	♀ vi–iii	0+33	56
676	1·4	4·68	11·4	12·35	14·3	17·3	22·5	23·7	26·5	15	17	3+16	3+14	137	♀ iv–v	†0+33	56
677	1·4	4·7	11·5	12·35	14·45	17·0	22·35	23·7	26·3	15	17	3+16	1+3+14	144	♂ vi	1+31	55
678	1·4	4·52	10·9	11·9	13·65	16·6	21·75	22·95	25·4	15	17	3+16	3+14	108	♂ vii	2+31	56
679	1·45	4·65	11·5	12·5	14·3	17·3	22·65	23·9	26·7	15	17	3+17	3+13	138	♂ vi	1+33	56
680	1·43	4·64	11·5	12·3	14·25	17·4	22·4	23·6	26·3	14	17	3+16	3+15	162	♀ vi	0+32	56
681	1·38	4·4	11·0	12·0	13·95	16·75	22·05	23·3	25·9	15	16	3+17	4+14	157	♀ vi	2+32	56
682	1·38	4·63	11·3	12·25	14·4	17·15	22·35	23·55	26·3	15	17	3+17	4+13	126	♀ vii	0+33	56
683	1·46	4·75	12·3	12·6	15·25	17·45	22·9	24·2	26·9	13	17	3+15	4+14	181	♂ v–vi	1+32	55
684	1·52	4·8	12·0	13·2	14·9	18·2	23·35	24·65	27·45	14	17	3+16	4+14	161	♂ vi	2+30	55
685	1·46	4·65	11·75	12·5	14·4	17·55	22·45	23·7	26·5	15	18	2+16	3+14	147	♂ v–vi	†0+32	55
686	1·55	4·8	11·7	12·75	14·9	17·9	23·3	24·55	27·45	15	16	3+17	3+15	161	♀ v	1+32	56
687	1·4	4·5	11·1	12·3	13·9	17·05	22·0	23·25	25·75	15	17	3+16	4+13	125	♂ iv–v	*1+31	55
688	1·65	4·9	11·55	12·75	14·3	17·7	22·8	24·0	26·6	16	17	3+16	4+13	136	♂ iv–v	2+32	57
689	1·45	4·6	11·45	13·05	14·3	17·85	23·2	24·45	27·1	14	16	3+17	3+14	166	♂ vi	1+33	56
690	1·5	4·75	11·65	12·5	14·65	17·6	22·85	24·1	26·8	15	16	3+16	4+15	146	♀ vi–iii	1+33	56
691	1·3	4·15	10·1	10·9	12·7	15·4	20·2	21·2	23·65	16	18	3+18	3+15	98	♀ vii	0+32	56
692	1·45	4·52	11·3	12·4	14·2	17·2	22·4	23·65	26·2	15	17	3+17	3+15	142	♂ vi	2+32	56
693	1·47	4·6	11·2	12·5	13·9	17·15	21·8	23·05	25·7	15	17	4+16	3+13	146	♀ v	1+33	56
694	1·5	4·65	11·4	12·4	14·05	17·2	22·5	23·65	26·35	15	17	3+17	3+14	139	♂ vi	2+32	56
695	1·48	4·55	11·4	12·1	14·35	17·05	22·15	23·25	25·75	15	16	3+17	3+14	140	♀ vi–iv	2+31	56
696	1·34	4·4	10·9	11·85	13·55	16·7	21·85	23·0	25·5*	15	17	3+16	3+14	125	♂ vi	1+32	56
697	1·46	4·7	11·85	12·4	14·65	17·45	22·55	23·7	26·4	14	17	3+16	2+16	125	♀ vi–iii	0+32	55

No. of fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
698	1·42	4·93	12·6	13·7	15·3	18·9	24·3	25·7	28·1*	14	17	Damaged. 3+13	4+13	156	♂ vi	2+31	55
699	1·46	4·7	11·25	12·75	14·3	17·65	22·8	24·0	26·7	15	16	2+16	3+13	143	♀ vi	†0+31	55
700	1·6	4·9	11·9	13·0	15·2	18·2	23·25	24·45	27·25	16	16	3+17	3+14	149	♂ v–vi	2+32	56
701	1·5	4·55	11·75	12·45	14·55	17·4	22·65	23·85	26·5	15	16	3+16	2+14	149	♂ vi	1+32	56
702	1·7	5·45	13·6	14·1	16·7	19·7	25·7	27·15	30·15	14	17	3+16	3+15	215	♀ vi	0+32	55
703	1·75	5·55	12·9	13·7	16·0	18·8	24·4	25·7	28·6	15	16	3+16	3+14	142	♂ vi–iii	1+32	55
704	1·5	4·9	12·3	13·25	15·3	18·0	23·6	24·9	27·75	14	18	3+16	4+13	144	♂ v	0+32	56
705	1·52	4·92	12·45	13·1	15·6	18·6	24·25	25·6	28·4	15	17	3+16	3+16	185	♀ vi	0+33	56
706	1·6	4·8	11·8	12·7	14·5	17·75	22·9	24·15	26·6	15	18	3+16	3+14	143	♂ vi–iv	1+32	56
707	1·43	4·38	11·15	11·65	13·85	16·35	21·6	22·75	25·3	14	18	3+16	3+15	136	♂ v	1+33	56
708	1·5	4·9	12·0	12·9	14·8	17·9	23·3	24·5	27·2	15	16	3+16	3+15	150	♂ v–vi	1+33	56
709	1·7	5·33	12·8	13·7	15·9	18·7	24·6	25·9	28·8	14	17	3+17	3+15	199	♂ vi	1+32*	56
710	1·52	4·8	12·4	13·2	15·55	18·65	23·95	25·15	27·85	15	18	3+16	3+13	201	♀ vi	2+32	56
711	1·43	4·35	11·6	12·3	14·4	17·35	22·55	23·7	26·45	16	17	3+16	3+14	158	♂ vi	0+33	55
712	1·4	4·4	11·1	11·95	13·8	16·7	21·4	22·55	25·05	16	18	3+16	3+14	129	♂ vi	2+31	56
713	1·5	4·8	11·75	12·6	14·65	17·4	22·85	24·1	26·8	15	17	2+17	3+15	148	♂ vi	2+32	56
714	1·6	5·0	12·2	12·9	15·2	18·1	23·45	24·8	27·4*	14	16	3+16	3+15	185	♂ vi	2+31	55
715	1·4	4·42	10·95	12·1	13·7	16·95	22·1	23·3	25·85	15	17	3+16	3+14	153	♂ vi	0+33	56
716	1·52	4·7	11·65	12·4	14·45	17·65	22·8	24·1	26·9	15	16	3+16	3+16	151	♀ vi	1+32	56
717	1·6	4·82	11·75	12·8	14·75	17·8	23·2	24·5	27·0	15	17	3+16	3+14	151	♂ iii–iv	0+33	56
718	1·45	4·8	11·7	12·35	14·5	17·2	22·65	23·85	26·45	16	17	3+16	3+14	142	♂ v–vi	1+32	56
719	1·6	4·6	11·6	12·3	14·3	17·3	22·5	23·7	26·2	15	16	3+17	3+14	129	♀ vi–iii	1+32	56
720	1·4	4·35	10·75	11·9	13·45	16·55	21·55	22·65	25·25	14	16	3+16	3+15	131	♂ v	†2+32	56
721	1·47	4·85	11·6	12·2	14·35	17·0	22·45	23·6	26·2	14	17	3+16	3+16	140	♂ vi	1+33	56
722	1·48	4·66	11·6	12·9	14·45	17·8	22·95	24·2	26·95	14	16	3+16	3+15	161	♂ vi	2+32	56
723	1·45	4·55	11·3	12·25	14·2	17·0	22·1	23·25	26·0	15	16	3+16	3+14	142	♀ vi–iv	1+32	56
724	1·57	4·7	11·5	12·45	14·05	17·1	22·3	23·55	26·3	12	17	2+16	3+15	143	♂ iii	1+31	55
725	1·67	5·05	12·45	13·5	15·35	18·8	23·9	25·2	28·1	15	17	3+16	3+14	168	♀ v	0+33	55
726	1·5	4·85	12·05	12·55	14·85	17·4	22·7	23·9	26·6	14	16	3+17	17 (3+14 probably.)	138	♂ v	1+32	56
727	1·46	4·54	11·6	12·2	14·4	17·3	22·15	23·35	25·9	15	18	3+16	4+13	144	♀ iv–v	0+33	56
728	1·47	4·8	11·8	12·9	14·7	17·8	22·8	24·0	26·8	15	18	3+16	3+14	154	♂ vi	0+34	56
729	1·5	4·68	11·45	11·9	14·2	17·4	22·4	23·65	26·25	14	16	3+15	3+13	139	♀ vi–iii	1+32	56
730	1·52	4·76	11·7	12·35	14·5	17·25	22·7	23·9	26·5	14	17	3+16	1+3+14	143	♂ v	2+32	56
731	1·5	4·95	11·85	12·65	14·8	17·4	22·8	24·05	26·8	13	18	3+17	3+14	154	♂ vi	2+31	56
732	1·78	5·42	13·4	14·1	16·35	19·7	25·55	26·95	29·6*	15	17	3+16	3+14	185	♀ vi–iv	2+32	56
733	1·73	5·4	13·05	13·85	16·4	19·2	24·85	26·15	29·15	14	17	3+17	1+3+13	179	♂ vi	1+32	55
734	1·5	4·8	12·0	12·95	15·15	18·1	23·3	24·6	27·4	15	17	2+17	3+14	179	♀ vi	1+31	55

735	1·5	4·7	11·95	12·75	15·1	18·35	23·65	24·9	27·65	16	17	4+16	3+14	182	♀ vi	1+32	56
736	1·45	4·32	11·35	12·4	14·15	17·25	22·15	23·4	26·0	15	17	3+16	3+15	153	♂ vi	†0+32	56
737	1·7	5·3	13·3	14·25	16·4	19·7	25·4	26·7	29·55	14	17	3+16	3+14	164	♀ vii	2+31	55
738	1·7	5·3	12·95	14·1	16·4	19·35	25·3	26·8	29·9	14	17	3+16	3+14	200	♂ vi	2+31	56
739	1·4	4·5	11·75	11·9	14·6	17·2	22·5	23·75	26·15	15	18	3+16	3+14	144	♂ v	1+31	55
740	1·4	4·88	12·2	13·15	15·35	18·15	23·65	24·95	27·3*	14	16	3+17	3+14	182	♂ v–vi	0+33	56*
741	1·48	4·65	12·0	12·6	14·7	17·6	22·9	24·15	26·85	14	17	3+16	3+14	143	♂ v	2+31	56
742	1·5	4·6	11·55	12·1	14·45	17·1	22·4	23·6	26·05	15	16	3+16	3+14	158	♂ vi	1+33	57
743	1·4	4·4	11·25	12·05	14·05	16·9	21·9	23·1	25·65	15	17	3+16	4+12	143	♀ vi	0+32	56
744	1·5	4·95	11·85	12·7	14·6	17·7	23·25	24·45	27·15	12	16	3+15	3+14	138	♀ i–ii	0+32	55
745	1·5	4·56	11·3	12·25	14·05	17·4	22·2	23·5	25·85	15	17	3+16	3+14	150	♂ v	2+33	57
746	1·5	4·67	11·35	12·1	14·1	17·05	22·0	23·3	25·9	15	16	3+16	3+14	138	♂ iii	2+31	54*
747	1·58	4·6	11·4	12·4	13·9	17·25	22·25	23·4	25·9	14	17	3+16	3+14	155	♂ vi	1+32	55
748	1·34	4·35	11·25	12·0	13·75	16·5	21·4	22·4	25·0	14	16	3+15	3+13	129	♂ vi	1+31	56
749	1·45	4·73	12·1	12·85	15·15	18·0	23·25	24·55	27·1	15	16	3+16	3+14	155	♂ v	0+32	55
750	1·4	4·57	11·4	12·0	14·3	17·0	22·35	23·55	26·25	15	17	3+16	3+14	168	♂ v	1+33	56
751	1·58	4·9	11·65	12·9	14·7	17·9	23·0	24·3	27·05	15	18	3+17	3+14	125	♀ vii	0+33	56
752	1·74	5·1	12·15	13·1	15·05	18·4	24·1	25·4	28·2	14	17	3+16	3+15	160	♀ vi–iv	1+33	56
753	1·74	4·95	12·4	13·15	15·4	18·45	23·95	25·2	28·05	15	16	3+16	3+15	192	♀ vi	1+32	56
754	1·74	5·3	12·6	13·4	15·35	18·25	23·65	24·95	27·85	13	18	3+15	3+14	164	♂ vi	2+32	56
755	1·55	4·67	11·8	12·5	14·85	17·3	22·95	24·1	26·7	15	17	3+17	3+15	153	♀ iv–v	2+32	56
756	1·45	4·4	11·25	12·25	14·05	16·75	21·85	22·95	25·7	15	17	3+16	3+13	158	♀ vi	†1+31	55
757	1·5	4·64	11·5	12·4	14·35	17·05	22·2	23·35	26·0	14	18	3+16	1+2+16	165	♂ v	2+32	56
758	1·56	4·87	11·6	12·55	14·4	17·7	22·8	23·95	26·55	14	18	3+17	3+15	148	♂ vi	1+33	56
759	1·5	4·75	11·85	12·7	14·6	17·45	22·85	24·15	26·45	15	17	3+16	3+15	145	♀ vi	2+32	56
760	1·55	4·88	12·25	12·65	15·0	18·6	23·4	24·7	27·2	15	18	3+16	17 rays broken.	175	♂ v	0+33	56
761	1·38	4·2	10·6	11·4	13·15	16·15	20·7	21·9	24·6	14	16	3+16	3+13	122	♀ vi	2+30	55
762	1·55	5·0	12·3	13·2	15·3	18·6	23·9	25·15	28·05	14	17	3+16	3+14	162	♂ v	1+31	55
763	1·45	4·5	11·35	12·4	14·1	17·3	22·4	23·55	26·4	15	17	3+17	3+13	151	♀ vi	1+32	55
764	1·43	4·5	11·7	12·3	14·4	17·45	22·7	23·95	26·6	15	16	3+16	3+14	154	♂ v	†0+33	56
765	1·7	5·1	12·65	13·5	15·85	18·65	24·1	25·45	28·3	16	17	3+17	3+14	179	♀ vi	1+33	56
766	1·64	4·9	12·5	13·0	15·35	18·55	23·7	25·05	27·9	16	17	3+16	3+14	167	♂ vi	1+33	56
767	1·7	5·1	12·3	13·9	15·5	18·8	24·3	25·6	28·3	15	17	3+17	1+14	181	♀ vi	2+32	55*
768	1·55	4·6	11·75	13·0	14·6	17·7	23·0	24·3	26·85	14	17	3+15	4+14	151	♀ vi	1+0+33	56
769	1·55	4·8	11·75	12·65	14·8	18·1	23·4	24·7	27·25	14	16	3+17	3+14	162	♀ vi	0+33	55
770	1·42	4·57	11·4	12·1	14·2	17·25	22·05	23·25	25·85	16	17	3+16	3+14	151	♀ v	†0+32	56
771	1·6	4·64	11·75	12·5	14·45	17·5	22·9	24·2	26·95	14	16	3+16	3+15	159	♀ vi	1+33	56
772	1·6	4·83	11·95	12·2	14·8	17·8	22·8	24·0	26·8	16	16	3+17	4+13	162	♂ vi	0+32	55
773	1·62	4·72	11·7	12·85	14·65	17·85	23·05	24·25	26·7	15	16	3+16	3+13	160	♀ iv–v	0+33	56
774	1·57	4·66	11·6	12·25	14·2	17·25	22·5	23·8	26·3	14	17	3+16	3+14	136	♂ v	†1+31	55
775	1·56	4·78	11·4	12·7	14·1	17·3	22·55	23·75	26·3	14	16	3+16	3+13	120	♀ vi–iii	1+33	56
776	1·52	4·6	11·8	12·3	14·6	17·55	22·7	23·95	26·4	16	17	3+17	3+15	141	♂ iv	2+32	56

No. of fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
777	1·52	4·88	11·5	12·4	14·4	17·45	22·6	23·75	26·3	15	17	3+15	4+13	125	♂ iv	2+32	56
778	1·5	4·56	10·95	11·6	13·45	16·3	21·2	22·4	24·9	15	17	3+17	3+15	119	♂ iv–v	0+32	56
779	1·3	4·68	9·85	10·35	12·35	14·5	19·25	20·35	22·65	15	18	2+17	3+15	80	♂ vi–iii	1+32	56
780	1·65	4·9	11·9	12·6	14·8	17·85	22·95	24·3	27·05	15	17	4+16	4+14	154	vi	†0+34	57
781	1·4	4·52	11·25	12·05	13·9	16·95	22·15	23·3	26·0	15	17	3+16	3+16	131	♂ vi	1+33	56
782	1·52	5·0	12·1	13·4	14·9	17·9	23·2	24·55	27·35	14	17	2+17	3+15	141	♀ vii	†0+31*	54
783	1·45	4·45	10·7	11·4	13·3	16·15	21·3	22·5	24·95	15	17	3+15	3+14	124	♀ v	1+32	55
784	1·5	4·6	11·45	12·2	14·4	17·2	22·4	23·6	26·2	15	17	3+16	3+15	146	♀ vi	†0×[*1+1+31]	55
785	1·4	4·32	10·8	11·6	13·6	16·1	21·25	22·45	25·1	16	17	3+16	3+15	125	♂ vi–iv	1+31	55
786	1·72	5·1	12·8	13·9	15·9	19·1	24·6	25·95	28·8	15	17	3+17	4+15	184	♀ vi	2+31	56
787	1·65	4·9	12·15	13·0	15·0	18·1	23·25	24·4	27·0	15	17	3+16	3+15	157	♀ vi	2+32	56
788	1·5	4·5	11·25	12·4	14·15	16·9	22·15	23·35	25·85	13	17	3+17	4+15	138	♂ v	0+33	56
789	1·5	4·6	11·3	12·25	14·0	16·8	21·9	23·05	25·65	15	17	3+16	3+15	136	♂ vi	0+32	55
790	1·57	5·1	12·5	13·2	15·55	18·55	24·05	25·35	28·25	4+0+9	16	3+16	3+14	165	♂ vi	2+31	56
791	1·5	4·45	11·0	11·85	13·95	16·8	21·7	22·9	25·5	14	17	4+17	3+14	136	♀ vi	2+31	55
792	1·34	4·16	10·55	11·5	13·2	15·95	20·8	21·9	24·5	15	17	3+17	3+15	113	♂ vi	1+32	56
793	1·5	4·74	11·65	12·8	14·35	17·5	22·8	24·1	26·9	13	16	3+15	3+13	161	♂ v	1+32	55
794	1·44	4·45	11·1	12·3	14·2	16·95	22·05	23·2	25·75	15	17	3+16	3+16	139	♂ vi	†2+31	56
795	1·47	4·72	11·8	13·15	14·7	18·3	23·25	24·45	27·35	16	17	3+17	3+14	153	♂ vi	1+32	56
796	1·6	5·07	12·0	13·2	15·25	18·15	23·5	24·8	27·6	14	17	3+17	3+15	153	i–ii	1+31	55
797	1·42	4·44	11·4	11·9	14·05	17·05	22·3	23·4	26·1	15	17	3+16	3+16	138	♂ vi	†1+32	56
798	1·46	4·77	12·1	12·9	14·8	17·95	23·05	24·3	26·9	15	17	3+16	3+13	152	♀ vi	1+32	55
799	1·6	5·0	12·35	13·8	15·4	18·7	24·2	25·6	28·4	14	18	3+17	3+15	146	♀ vii	†0+32	56
800	1·46	4·7	11·1	12·3	14·05	16·8	21·85	23·0	25·85	15	17	3+17	3+14	133	vi	1+32	56
801	1·56	4·75	11·4	12·4	14·0	16·95	22·1	23·25	25·85	14	16	3+16	4+14	127	♀ vi	0+32	55
802	1·55	4·6	11·6	12·35	14·55	17·7	22·6	23·8	26·5	15	16	3+16	3+14	147	♀ vi	1+31	54
803	1·5	4·65	11·95	12·8	14·8	17·65	22·85	24·15	26·55	15	16	3+16	3+13	161	♀ vi	†0+33*	56
804	1·5	4·52	10·9	11·75	13·7	16·05	21·55	22·7	25·35	14	17	3+16	3+15	122	♂ vi	0+32	56
805	1·34	4·36	10·7	11·7	13·3	16·1	21·1	22·25	24·7	14	17	3+17	3+15	116	♂ vi	2+32	56
806	1·6	4·8	12·2	13·2	15·2	18·1	23·5	24·75	27·7	15	17	3+16	3+15	155	♀ iv–v	0+32	55
807	1·5	4·58	11·5	12·35	14·65	17·2	22·35	23·5	26·2	15	15	3+17	3+14	126	♀ vi–iii	1+32	56
808	1·5	4·7	11·65	12·2	14·35	17·0	22·6	23·8	26·45	15	16	4+15	4+14	138	♂ vi	0+32	55
809	1·53	4·55	11·35	12·35	14·0	17·1	22·0	23·35	25·75	14	16	3+16	1+3+14	133	♀ vi	1+32	57
810	1·5	4·8	11·3	11·6	14·1	16·7	22·0	23·2	25·85	16	17	4+16	3+14	101	♀ vii	2+32	56
811	1·55	4·82	11·3	12·1	14·25	16·8	22·2	23·55	26·25	14	17	3+17	1+3+15	133	♂ vi	2+32	55
812	1·52	4·8	11·8	12·5	14·75	17·35	22·8	23·95	26·55	15	17	3+16	3+15	164	♂ v–vi	0+33	55
813	1·4	4·54	11·1	12·15	13·85	16·75	22·05	23·3	26·0	15	17	3+17	3+15	135	♀ vi	†0+33	56
814	1·7	4·93	11·8	12·65	14·55	17·6	22·85	24·05	26·7	15	16	3+17	3+13	151	♀ vi	†0+32	56
815	1·52	4·84	12·2	13·1	14·9	18·4	23·4	24·65	27·4	11+0+4	17	3+16	1+3+14	176	♂ v	1+32	56

816	1·38	4·2	9·8	10·7	12·2	14·85	19·24	20·3	22·5	15	17	3+17	1+3+15	72	♀ vii	†0+33	56
817	1·36	4·47	11·35	12·05	14·2	16·6	21·85	23·13	25·75	15	17	2+17	3+15	126	♂ vi–iv	0+33	56
818	1·6	4·9	12·3	12·65	15·3	18·0	23·7	24·9	27·15*	13	Rt. broken, l. 17.	3+16	3+14	127	♀ i–ii	1+33	57
819	1·32	4·3	10·7	11·4	13·3	15·9	20·85	22·0	24·45	15	16	3+16	3+15	113	♂ vi	1+32	55
820	1·58	5·1	11·85	13·2	15·1	17·95	23·2	24·45	27·25	16	16	3+17	3+13	126	♂ vii	3+30	56
821	1·5	4·38	10·65	11·55	13·15	16·0	20·75	21·9	24·45	15	17	2+17	3+14	105	♀ vii	†0+33	56
822	1·5	4·7	11·6	12·5	14·4	17·1	22·15	23·45	26·2	15	17	3+17	3+14	118	♀ vi–iv	2+31	56
823	1·6	4·95	11·95	12·3	14·9	17·25	22·9	24·05	26·9	15	17	3+16	3+15	139	♂ vi	1+32	55
824	1·47	4·4	10·75	11·7	13·55	15·85	21·0	22·15	24·7	14	17	3+16	1+2+16	114	♂ vi	†1+31	55
825	1·4	4·47	10·95	11·4	13·9	16·4	21·2	22·35	24·75	16	16	4+17	3+15	116	♂ vii	1+32	56
826	1·34	4·24	10·45	11·45	13·4	16·1	21·2	22·35	24·95	15	17	3+17	3+14	122	♂ vi	2+31	56
827	1·5	4·65	11·4	12·2	14·25	16·95	22·1	23·45	26·05	15	17	4+16	3+15	127	♂ vi	1+32	56
828	1·6	4·65	11·85	12·7	14·65	17·7	23·0	24·3	26·95	15	17	3+16	3+14	152	♀ v–vi	0+33	56
829	1·6	4·85	12·5	13·45	15·40	18·7	24·1	25·4	28·2	15	17	3+17	3+14	167	♀ vi	0+33	56
830	1·45	4·7	11·6	12·6	14·55	17·4	22·1	23·5	26·2	15	16	3+16	1+3+14	152	♂ vi	2+31	55
831	1·4	4·42	11·7	12·4	14·65	17·5	22·8	24·0	26·5	15	17	2+16	3+13	153	♀ v	†0+32	55
832	1·36	4·34	11·1	12·05	13·9	16·3	21·6	22·8	25·35	13	16	3+17	1+3+15	139	♀ vi	†0+32	56
833	1·5	4·75	11·75	12·85	14·64	17·9	23·1	24·3	27·0	16	17	3+17	3+14	149	♂ v	2+30	55
834	1·37	4·3	10·55	11·15	13·05	15·8	20·55	21·8	24·3	15	18	4+15	1+3+14	122	♂ vi	1+32	55
835	1·4	4·38	11·1	11·7	13·9	16·65	21·9	23·1	25·7	15	17	3+16	1+3+14*	138	♂ vi	3+31	56
836	1·3	4·1	10·1	11·1	12·75	15·4	20·2	21·4	24·0	13	17	3+17	3+15	121	♂ vi	1+31	55
837	1·45	4·3	10·8	11·5	13·55	16·15	21·0	22·3	24·9	15	17	3+17	3+16	123	♀ vi	1+32	55
838	1·37	4·53	11·05	11·75	13·75	16·5	21·5	22·75	25·3	13	16	2+17	3+15	110	♀ vii	1+32	55
839	1·43	4·8	11·65	12·55	14·75	17·55	22·9	24·2	26·9	16	17	3+16	3+14	130	♂ vi	3+31	55
840	1·7	5·0	12·25	13·55	15·6	18·75	24·0	25·25	28·0*	14	16	3+17	3+14	191	♀ vi	2+31	55
841	1·7	5·12	12·3	12·9	15·15	18·4	23·85	25·1	27·85	15	16	3+16	1+3+15	188	♀ v	†0+33	58*
842	1·4	4·52	11·0	11·73	13·75	16·6	21·65	22·7	25·05	15	16	3+17	3+15	111	♂ i–ii	0+32	55
843	1·6	4·74	11·85	12·8	14·95	18·0	23·25	24·5	27·05	15	18	3+16	1+2+15	153	♀ vii	0+34*	56
844	1·56	5·03	12·85	13·85	16·0	19·0	24·55	25·8	28·65	15	16	3+17	2+14	178	♂ vi	1+32	56
845	1·45	4·44	11·0	12·05	13·9	16·7	21·65	22·85	25·3	15	17	3+16	3+14	111	♂ vi–iv	0+32	56
846	1·5	4·5	10·75	11·55	13·55	16·0	20·9	22·1	24·55	14	17	3+17	3+15	122	♂ vi	1+32	56
847	1·56	4·85	12·3	12·9	14·95	18·5	23·6	24·95	27·35	16	17	3+16	3+14	168	♀ vi	1+33	56
848	1·5	4·65	11·65	12·5	14·3	17·5	22·8	24·0	26·65	15	17	3+15	3+14	144	♀ vi	0+33	56
849	1·58	5·08	12·55	13·0	15·5	18·4	24·0	25·3	28·45	15	17	4+16	1+2+14	162	vi–iv	0+32	55
850	1·4	4·4	11·05	11·65	13·9	16·7	21·8	23·1	25·75	15	16	3+17	3+14	133	♂ v	1+32	56
851	1·6	4·9	11·75	12·4	14·85	17·5	22·8	24·2	26·75	15	16	3+17	3+14	170	♂ v	†0+33	56
852	1·68	4·92	12·55	13·45	15·85	19·05	24·45	25·75	28·55	14	17	3+17	1+3+15	204	♂ vi	0+33	56
853	1·6	4·8	11·55	12·95	14·55	17·85	23·1	24·35	27·2	14	17	3+17	1+2+16	172	♂ v–vi	1+33	57
854	1·52	4·46	11·15	12·25	14·0	17·15	22·25	23·5	25·95	14	17	3+16	3+15	159	♀ vi	4+30	56
855	1·5	4·67	11·7	12·55	14·6	17·65	22·65	23·9	26·35	15	16	3+17	3+14	164	♂ vi	0+32	55
856	1·4	4·58	11·5	12·4	14·2	17·4	22·4	23·6	25·75*	14	16	3+16	3+13	128	♀ iv–v	3+31	56

No. of fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
857	1·47	4·95	12·4	13·45	15·15	18·45	24·15	25·4	28·15	Fused. 4+(1+1)+8 13 or 14.	16	3+16	3+14	141	♀ i–ii	2+31	56
858	1·68	5·03	12·05	12·55	14·95	17·4	23·05	24·3	27·15	15	17	3+16	3+14	171	♀ vi	0+34	56
859	1·63	5·07	13·05	14·2	16·1	19·75	25·3	26·6	29·55	15	17	3+16	3+14	186	♂ vi–iv	2+31	56
860	1·62	4·9	11·9	12·95	14·75	17·9	23·3	24·65	27·5	15	17	3+16	3+15	150	♀ vi	1+32	56
861	1·52	4·62	11·7	12·75	14·5	17·9	23·1	24·3	26·9	15	16	3+16	1+3+14	150	♀ iv–v	1+33	56
862	1·58	5·0	12·55	13·2	15·25	18·4	23·9	25·3	28·05	16	17	4+16	3+14	163	♂ vi	2+31	56
863	1·54	4·78	11·9	12·65	14·8	17·85	23·05	24·35	27·0	14	17	3+17	1+3+12	138	♀ vi–iii	2+31	55
864	1·55	4·43	10·95	11·8	13·4	16·4	21·2	22·4	24·8	14	16	3+15	3+14	124	♂ v	1+31	55
865	1·47	4·5	11·35	12·45	14·3	17·5	22·45	23·7	26·25	15	17	3+16	3+15	156	♂ v	1+32	56
866	1·44	4·5	11·2	11·85	14·1	16·75	21·85	23·05	25·5	15	17	4+16	3+14	123	♀ vi	1+32	56
867	1·63	4·85	11·3	11·95	14·1	16·9	22·05	23·2	25·8	14	17	3+16	3+15	124	♂ vii	0+33	56
868	1·63	5·07	12·1	13·35	15·0	18·35	23·95	25·35	28·15	15	17	3+15	3+14	142	♀ i–ii	1+32	56
869	1·5	4·66	12·15	12·75	15·1	17·95	22·9	24·3	26·85	14	16	3+16	1+3+14	162	♂ v	0+32	55
870	1·55	4·62	12·0	12·95	14·75	17·75	23·2	24·4	27·08	15	17	3+16	1+3+14	164	♀ v	0+32	56
871	1·74	4·9	11·8	12·7	14·85	18·0	23·35	24·7	27·5	15	16	3+16	2+16	154	♂ vi	0+32	56
872	1·42	4·52	11·4	12·2	14·25	17·15	22·25	23·5	26·1	15	17	3+16	3+14	126	♂ vi–iv	1+33	56
873	1·37	4·36	11·35	11·9	14·3	16·95	22·2	23·45	26·05	15	16	3+17	3+16	168	♀ vi	1+33	57
874	1·6	4·8	11·8	12·2	14·55	17·4	22·4	23·75	26·25	14	16	3+17	3+13	134	♂ v	1+33	56
875	1·5	4·85	12·1	12·95	14·95	17·85	23·15	24·4	27·1	14	16	3+16	3+14	149	♀ vi–iii	1+32	56
876	1·6	4·86	12·1	12·7	15·1	17·95	23·25	24·5	27·1	15	17	2+17	3+14	175	♀ vi	1+31	56
877	1·5	4·4	11·1	12·1	13·95	16·9	22·0	23·3	26·0	16	16	3+16	4+14	150	♂ v–vi	1+32	55
878	1·35	4·2	10·4	11·25	13·0	15·6	20·4	21·5	24·0	14	18	3+17	3+14	118	♂ vi	1+31	54
879	1·52	4·7	11·55	12·15	14·4	17·1	22·3	23·5	26·2	15	17	3+16	3+15	136	♂ vi	2+32	56
880	1·5	4·34	10·85	12·2	13·5	16·4	21·25	22·4	24·85	14	17	3+16	3+15	128	♂ vi	1+32	56
881	1·65	5·2	12·7	13·35	15·6	18·85	24·3	25·55	28·5	15	17	2+17	3+14	182	♂ vi	0+33	56
882	1·4	4·46	11·2	12·0	14·0	16·75	21·95	23·15	25·7	14	17	3+16	3+15	127	♂ v–vi	0+33	56
883	1·55	5·0	12·1	13·2	15·05	18·35	23·75	25·1	27·7	15	18	3+16	3+14	164	♂ vi	1+33	57
884	1·6	4·7	12·1	12·7	15·0	17·7	23·05	24·35	27·0	15	17	3+16	2+14	142	♀ vi	1+32	56
885	1·57	4·7	11·85	12·65	14·55	17·9	23·0	24·25	27·1	1+14	16	3+16	3+12	155	♂ vi	3+31	55
886	1·5	4·64	11·25	12·0	14·15	16·95	22·1	23·2	25·75	14	16	3+15	4+13	127	♀ i–ii	0+32	55
887	1·45	4·4	10·7	11·5	13·5	16·05	20·9	22·0	24·6	14	17	3+17	3+14	119	♂ v	2+31	55
888	1·5	4·76	11·9	12·8	14·7	17·8	22·85	24·1	26·8	15	18	3+16	3+14	135	♂ vi–iii	1+32	56
889	1·57	4·8	11·7	12·7	14·25	17·7	22·85	24·0	26·55	16	17	3+15	2+15	137	♂ vi–iii	0+33	56
890	1·58	4·84	11·85	13·2	14·6	18·0	23·25	24·45	27·1	13	17	3+15	3+14	155	♀ iv–v	1+32	56
891	1·6	4·9	12·0	12·8	15·05	18·2	23·45	24·75	27·4	16	18	3+17	3+14	164	♀ v	1+34	57
892	1·64	4·73	11·6	12·8	14·55	17·6	22·9	24·1	26·9	15	16	3+17	3+16	151	♂ vi–iv	0+33	56
893	1·7	5·4	13·1	14·05	16·3	19·45	25·35	26·75	29·85	15	18	3+16	3+15	173	♂ vii–ii	2+31	55
894	1·52	4·6	11·8	12·65	14·55	17·5	23·1	24·35	26·95	15	16	3+16	3+14	157	♀ iv–v	2+32	56

895	1·54	4·58	11·15	12·05	13·7	16·9	21·85	23·05	25·75	14	18	2+16	3+14	125	♂ vi–iv	1+33	56
896	1·4	4·7	12·1	13·1	15·15	18·15	23·5	24·8	27·6	14	17	3+16	3+13	165	♂ vi	1+32	56
897	1·5	4·52	11·25	12·2	13·95	17·35	22·45	23·65	26·25	17	17	3+15	3+14	149	♂ v	1+32*	57
898	1·35	4·42	10·8	11·8	13·4	16·4	21·0	22·25	24·75	15	17	3+15	3+14	131	♂ vi iii	1+31	55
899	1·55	4·54	11·0	12·3	13·75	17·15	22·2	23·4	25·95	14	16	3+15	3+14	136	♂ iii–iv	2+31*	55
900	1·82	5·35	12·95	14·0	16·05	19·4	24·95	26·3	29·3	15	17	3+16	4+13	190	♀ vi–iii	1+32	56
901	1·5	4·5	11·2	12·1	13·9	17·0	22·0	23·2	25·8	14	17	3+15	3+12	135	♀ vi	1+32	56
902	1·5	4·5	11·1	12·0	13·9	16·85	21·55	22·7	25·2	15	18	3+17	3+14	153	♂ v	†0+32	55
903	1·47	4·66	11·15	12·4	13·85	16·85	22·2	23·4	26·05	14	17	3+15	3+13	128	♂ vi–iv	0+33	56
904	1·42	4·42	11·15	11·75	13·55	16·65	22·05	23·2	25·65	15	17	3+16	3+15	129	♂ vi	1+33	57
905	1·33	4·3	11·0	11·85	13·5	16·35	21·5	22·65	25·15	15	17	3+16	3+14	125	♀ iv–v	†0+32	55
906	1·5	4·67	12·0	13·05	15·0	17·07	22·95	24·2	26·9	15	16	3+16	4+14	159	♀ v	1+32	56
907	1·3	4·25	10·7	11·3	13·5	15·8	20·8	21·9	24·3	14	16	3+16	3+14	114	♂ vi	1+32	55
908	1·62	4·76	11·8	12·75	14·55	17·5	22·55	23·9	26·55	14	16	3+16	3+15	150	♂ vi	†1+32	56
909	1·54	4·6	12·2	12·6	15·1	17·85	23·0	24·3	27·45	15	17	3+16	3+15	154	♂ vi–iv	0+33	56
910	1·56	4·8	11·65	12·55	14·6	17·5	22·65	23·9	26·65	15	17	3+16	3+14	133	♂ v	0+32	55
911	1·55	4·6	12·0	13·15	15·35	18·2	23·45	25·04	27·3	15	17	3+17	4+13	184	♂ vi	0+32*	55
912	1·52	4·8	11·65	12·7	14·4	18·1	22·9	24·15	26·9	15	17	3+16	4+14	135	♀ vi–iv	0+32	55
913	1·56	4·6	11·95	12·9	14·8	17·75	23·1	24·4	27·0	16	17	3+16	4+14	171	♂ vi	1+32	56
914	1·43	4·27	10·4	11·65	13·1	16·15	20·75	21·9	24·45	15	16	3+17	3+14	115	♂ vi–iv	2+32	56
915	1·55	4·75	12·1	13·41	15·1	18·2	23·6	24·8	27·55	14	16	3+16	4+15	177	♂ v	1+32	55
916	1·52	4·77	11·5	12·4	14·4	17·25	22·5	23·75	26·35	14	17	3+17	4+15	131	♀ vi–iii	1+33	56
917	1·36	4·46	11·4	12·35	14·15	16·9	22·05	23·2	25·8	15	17	3+16	3+15	120	♀ vii	†2+31	56
918	1·5	4·6	11·45	12·45	14·25	17·4	22·5	23·75	26·25	15	16	3+16	4+14	142	♂ v	0+33	56
919	1·65	5·1	12·7	13·6	15·9	19·1	24·85	26·25	28·9	15	16	3+17	3+15	180	♂ vi	1+33	56
920	1·48	4·56	10·95	11·55	13·65	16·5	21·45	22·6	25·05	15	16	3+16	3+15	129	♂ vi	†1+32	55
921	1·46	4·26	10·15	11·25	12·7	15·75	20·0	21·15	23·45	16	18	3+16	3+14	95	♀ vi–iii	1+31*	55
922	1·45	4·7	11·45	12·4	14·45	17·5	22·55	23·8	26·45	15	18	3+17	3+14	151	♀ vi	0+33	56
923	1·58	4·65	11·75	12·3	14·6	17·9	22·95	24·3	27·0	16	17	3+15	2+13	163	♀ v–vi	2+32	56
924	1·6	5·07	12·2	13·0	15·2	18·2	23·6	24·9	27·8	16	16	2+16	4+14	182	♂ vi	1+33	56
925	1·58	4·72	11·65	12·5	14·55	17·6	22·6	23·8	26·2	14	16	3+16	3+15	145	♂ vi	0+33	56
926	1·46	4·5	11·5	12·2	14·15	16·9	22·05	23·25	25·9	14	17	3+16	3+15	128	♀ vi–iv	0+33	56
927	1·5	4·52	11·3	12·2	13·9	16·8	21·55	22·8	25·25	14	18	4+15	4+13	118	♀ vii	†1+32	55
928	1·52	4·9	12·7	13·5	15·75	18·7	24·1	25·45	28·15	15	17	3+16	2+15	195	♀ v	1+32	56
929	1·6	5·0	12·0	13·0	15·25	18·2	23·5	24·75	27·55	3+0+11	17	3+16	3+12+several broken away.	168	♂ v	1+32	56
930	1·6	4·8	11·4	12·4	14·2	17·5	22·6	23·8	26·5	15	18	3+16	3+14	147	♂ vi	3+30	55
931	1·72	5·1	12·45	13·4	15·45	18·7	24·1	25·35	28·0	15	16	3+16	3+14	153	♂ iii–iv	2+31	56
932	1·5	4·55	11·25	12·0	13·9	16·6	21·5	22·65	25·1	16	17	3+16	3+14	125	♂ vi	†0+32	55
933	1·4	4·26	10·45	11·15	13·0	15·6	20·2	21·35	23·37	15	16	4+16	3+14	101	♂ vi–iii	†0+32	55
934	1·48	4·48	11·3	12·4	14·2	17·2	22·6	23·83	26·35	15	17	3+17	3+15	137	♂ vi–iv	0+34	57
935	1·55	4·58	11·15	11·95	14·05	16·75	21·9	23·1	25·8	15	17	3+17	3+14	128	♂ vi–iv	1+32	56

No. of Fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
936	1·42	4·3	10·7	11·1	13·3	16·0	20·4	21·65	23·8	14	16	3+15	3+15	122	♂ vi	1+32	55
937	1·5	4·7	12·0	12·4	15·05	17·8	23·15	24·3	26·93	16	17	3+16	18 fin broken.	161	♀ iv–v	2+30	55
938	1·78	5·34	13·3	14·35	16·6	19·4	25·4	26·8	29·8	14	17	3+16	3+15	190	♀ vi	3+32	56
939	1·46	4·7	12·4	13·3	15·05	18·6	24·0	25·3	27·8	14	16	3+15	1+3+13	152	♀ vi–iii	2+31	56
940	1·48	4·75	11·8	12·8	14·65	17·7	22·9	24·25	26·85	14	18	3+17	3+14	146	♂ vi	0+32	55
941	1·55	4·72	11·2	12·0	14·0	17·0	22·2	23·55	26·1	16	17	3+16	3+14	137	♂ vii	1+34	57
942	1·6	4·94	12·0	12·9	15·0	18·3	23·4	24·65	27·4	15	17	3+16	3+13	172	♀ v–vi	1+32	55
943	1·53	4·85	11·65	12·85	14·9	17·7	23·25	24·55	27·15	14	17	3+17	3+14	138	♂ vii	0+32	54*
944	1·5	4·86	12·05	12·55	15·05	17·6	22·75	23·9	26·5	15	17	3+16	3+16	137	♀ vi–iii	2+32	57
945	1·5	4·86	12·5	13·4	15·6	18·8	24·35	25·65	28·4	14	16	3+17	3+16	199	♀ vi	0+32	56
946	1·68	5·18	12·55	13·3	15·65	18·9	23·9	25·25	28·05	15	17	3+17	3+14	176	♂ v	2+33	56
947	1·52	4·5	11·2	12·0	14·05	16·8	22·1	23·3	25·85	15	17	3+16	4+15	138	♀ v	†1+31	55
948	1·5	4·6	11·4	12·85	14·25	17·6	22·7	23·95	26·25*	15	16	3+15	3+14	155	♀ vi	1+32	56
949	1·46	4·6	11·7	12·1	14·4	17·3	22·73	23·9	26·45	15	16	3+16	4+14	138	♀ vi–iv	Missing 1+0+31	55
950	1·55	5·0	12·7	13·3	15·55	18·2	24·1	25·35	28·1	13	17	3+16	4+15	168	♂ vi–iv	1+32	55
951	1·48	4·5	11·1	12·2	13·9	16·65	21·85	23·05	25·7	13	17	3+16	3+15	132	♂ vi–iv	2+31	55
952	1·47	4·82	11·7	12·5	14·8	17·85	23·05	24·2	26·85	18	16	3+17	3+15	171	♀ vi	0+34	57
953	1·65	4·86	12·0	12·85	14·9	17·55	22·8	24·05	26·8	14	17	3+16	3+14	135	♀ vi	2+31	56
954	1·55	4·62	11·2	12·45	14·0	17·3	22·15	23·3	25·95	15	17	3+17	3+14	149	♀ vi	1+31	56
955	1·38	4·48	11·2	11·75	13·7	16·95	21·8	23·05	25·7	14	17	2+16	3+15	153	♂ v	1+33	56
956	1·67	5·0	12·25	13·3	15·2	18·4	23·95	25·15	27·75	14	17	3+16	3+15	171	♀ vi	0+32	56
957	1·5	4·65	11·5	12·8	14·5	17·6	22·7	23·9	26·65	14	17	2+17	3+14	171	♀ vi	0+32	56
958	1·56	4·78	11·7	12·6	14·65	17·5	22·8	23·95	26·6	15	16	2+17	3+14	175	♂ v	0+33	56
959	1·52	4·75	11·95	12·7	15·0	17·85	23·25	24·5	27·05	14	18	3+16	2+14	168	♂ vi	0+34	56
960	1·38	4·3	11·2	11·45	13·95	16·5	21·6	22·75	25·4	14	15	3+17	3+14	127	♂ vi	1+32	55
961	1·52	4·45	10·7	11·65	13·55	16·38	21·25	22·35	25·05	15	17	3+17	3+14	132	♀ vi	2+31	56
962	1·44	4·57	10·95	11·0	13·65	15·8	20·65	21·85	24·45	15	18	3+17	4+14	116	♀ vi–iv	1+31	55*
963	1·33	4·57	11·6	12·0	14·25	16·6	22·1	23·3	25·9	14	17	3+16	3+16	128	♀ vii	1+32	55
964	1·62	4·88	12·15	12·85	15·0	17·9	23·1	24·3	27·1	16	16	3+17	4+15	155	♀ iv–v	0+32	55
965	1·3	4·28	10·25	11·05	12·9	15·45	20·05	21·15	23·65	14	17	2+17	3+15	118	♂ vi	2+31	55
966	1·42	4·4	10·9	11·85	13·9	16·1	21·2	22·35	24·85	14	16	2+17	3+15	107	♀ vi–iii	†0+33	57
967	1·5	4·86	12·2	12·95	15·05	18·35	23·7	24·95	27·8	14	17	3+15	4+13	146	♂ vi	0+32	56
968	1·3	4·22	10·5	11·2	12·9	15·35	20·05	21·1	23·5	14	16	3+16	3+15	106	♀ vi	†0+33	56
969	1·4	4·46	10·9	11·35	13·65	16·6	21·4	22·55	25·05	16	16	3+17	3+15	133	♂ vi	1+32	56
970	1·56	5·04	12·4	13·15	15·4	18·3	23·5	24·8	27·6	16	17	3+15	3+13	158	♂ vi	1+33	56
971	1·54	4·68	11·45	12·35	14·1	17·4	22·55	23·75	26·2	15	17	2+17	3+14	145	♀ vi	0+33	55
972	1·45	4·57	11·6	12·6	14·45	17·6	22·9	24·1	26·7	15	17	3+16	3+16	147	♀ vi	1+32	55
973	1·58	4·7	11·25	12·3	14·1	17·15	22·35	23·6	26·25	15	17	3+17	3+16	131	♂ vi	0+33	56

974	1·5	4·68	11·6	12·55	14·4	17·25	22·6	23·9	26·5	14	17	3+16	3+14	136	♀ vi	1+32	56
975	1·35	4·35	11·0	11·5	13·65	16·6	21·5	22·65	25·15	15	16	3+16	3+14	127	♀ v–vi	0+31	55*
976	1·5	4·6	11·55	12·05	14·65	17·2	22·5	24·0	26·7	14	16	3+17	3+16	136	♀ vii	1+32	56
977	1·48	4·63	11·0	11·65	13·75	16·3	21·1	22·28	24·7	15	16	3+17	3+13	106	♀ vi–iii	1+32	56
978	1·4	4·4	11·05	11·65	13·8	16·25	21·4	22·5	25·1	14	17	3+16	3+15	126	♀ vi	2+31	56
979	1·52	4·7	11·4	12·4	14·05	17·1	22·35	23·5	26·05	14	17	3+15	3+13	137	♂ v	2+31	56
980	1·52	4·66	11·75	12·65	14·8	17·5	22·8	23·95	26·7	15	16	2+17	3+13	157	♂ vi	0+33	56*
981	1·43	4·5	11·0	11·85	13·7	16·65	21·45	22·6	25·35	15	16	3+16	3+13	143	♀ vi	0+32	55
982	1·57	4·77	11·35	11·55	14·2	16·45	21·95	23·2	25·8	15	17	2+17	3+14	126	♂ vii	1+33	57
983	1·3	4·26	10·55	11·2	13·1	15·6	20·45	21·55	24·0	15	18	3+15	3+15	103	♀ vi–iv	2+33	57
984	1·66	5·15	12·55	13·7	15·45	18·85	24·05	25·4	28·3	14	16	3+15	3+13	152	♀ i–ii	2+30	55
985	1·42	4·72	12·0	13·2	15·2	18·65	24·05	25·3	28·35	16	16	4+16	3+14	185	♀ v–vi	1+32	56
986	1·53	4·4	11·4	12·0	14·0	17·0	22·1	23·25	25·9	15	17	3+16	3+14	132	♀ vi	1+32	56
987	1·42	4·26	10·56	11·4	13·15	16·4	21·25	22·4	24·75	16	17	3+16	4+13	117	♀ iv–v	1+33	57
988	1·54	4·66	11·6	12·4	14·3	17·55	22·9	24·05	26·7	15	16	3+15	3+13	145	♀ vi	†1+33	57
989	1·65	5·0	12·5	13·75	15·2	18·6	24·3	25·55	28·25	15	18	3+16	3+16	156	♀ vi	2+32	56
990	1·72	5·03	12·15	13·4	15·25	18·55	23·85	25·1	27·95	15	16	3+17	3+14	171	♀ vi	1+32	56
991	1·52	4·75	11·9	12·8	14·8	18·1	23·35	24·7	27·5*	14	17	3+16	1+3+14	171	♂ vi	0+32	55
992	1·68	5·05	12·35	13·15	15·3	18·35	24·0	25·3	28·15	14	17	3+16	4+14	147	♀ i–ii	2+31	55
993	1·47	4·67	11·45	12·4	14·15	17·65	22·6	23·85	26·45	15	17	3+16	3+13	149	♀ iv–v	1+33	56
994	1·48	4·53	11·0	11·6	13·95	16·4	21·45	22·6	25·05	14	17	3+17	4+14	134	♂ vi	†0 or 1+33	56
995	1·5	4·52	11·35	12·35	14·0	17·4	22·15	23·35	25·9	14	17	3+16	18 ray broken.	123	♂ vii	2+32	56
996	1·65	4·96	12·6	13·45	15·6	18·9	24·15	25·5	28·4	15	Fused. 9+(1+1)+5	3+15	4+14	191	♀ v	1+31	55
997	1·62	4·83	12·2	12·8	14·85	18·2	23·6	24·95	27·8	15	16	3+16	3+13	164	♀ vi	1+32	56
998	1·47	4·8	11·35	12·35	14·15	17·2	22·5	23·75	26·25	15	16	3+17	3+14	124	♂ vi–iv	1+33	57
999	1·6	4·8	12·1	12·9	15·0	18·15	23·3	24·6	27·3	14	17	2+15	3+14	173	♀ vi	1+33	57
1000	1·66	4·8	11·75	12·0	14·9	17·3	22·6	23·95	26·55	15	17	3+16	2+15	143	♂ v	1+32	54
1001	1·4	4·58	11·74	12·6	14·65	17·95	23·05	24·35	27·0	14	17	2+17	3+15	163	♀ vi–iii	1+32	56
1002	1·7	5·0	12·2	12·95	15·1	17·8	23·0	24·3	26·95	14	16	3+16	3+13	157	♂ v	2+31	56
1003	1·52	4·97	11·85	12·55	14·5	17·4	23·05	24·4	26·95	14	17	3+15	3+14	163	♂ vi	1+32	55
1004	1·4	4·7	11·8	12·15	14·7	17·45	22·65	23·85	26·55	14	17	3+16	3+15	152	♀ v	2+32	56
1005	1·9	5·74	14·1	14·77	17·45	20·6	26·7	28·1	31·2	15	17	3+16	3+14	218	♂ vi	2+31	57
1006	1·72	5·0	12·5	13·1	15·6	18·2	23·8	25·03	27·6	15	16	3+16	2+15	175	♂ vi	1+33	56
1007	1·6	5·0	12·65	14·0	15·75	18·9	24·35	25·7	28·6	14	17	3+17	3+14	184	♀ vi	1+32	56
1008	1·6	4·9	11·95	12·5	14·8	17·65	22·8	24·1	26·9	15	18	3+16	3+14	150	♂ vi	1+31	55
1009	1·65	5·0	12·0	12·55	14·9	17·55	22·9	24·2	27·1	15	18	3+17	3+15	159	♀ vi	1+32	56
1010	1·4	4·6	11·7	12·2	14·25	17·4	22·7	23·85	26·5	16	16	3+15	3+14	154	♂ vi	3+30	55*
1011	1·55	5·12	12·6	13·45	15·45	18·5	24·0	25·35	28·2	14	17	3+16	3+15	159	♂ vi–iii	0+33	56
1012	1·5	4·77	11·4	12·65	14·05	17·4	22·2	23·35	26·05	15	17	3+15	3+14	134	♂ vi	2+31	56
1013	1·52	4·75	11·7	12·87	14·7	17·8	23·2	24·5	27·15	15	16	Total 19. 3+16	3+16	151	♀ vi–iii	1+32	56
1014	1·63	4·9	12·0	13·2	15·05	18·15	23·45	24·7	27·55	14	16	3+16	2+15	167	♀ vi	1+33	56

No. of Fish.	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16	17	18
1015	1·43	4·5	11·15	11·7	13·9	16·3	21·35	22·65	25·1	13	15	3+15	3+14	128	♂ vi	2+32	56
1016	1·44	4·4	10·5	11·55	13·2	15·8	20·95	22·05	24·55	14	17	3+16	3+15	112	♂ vi	2+31	56
1017	1·5	4·66	12·35	13·15	15·45	18·5	23·8	25·05	27·85	14	17	3+16	3+14	167	vi	†1+32	56
1018	1·55	4·5	11·95	12·55	14·7	17·95	22·75	24·0	26·55	15	17	3+16	3+13	159	♂ v	2+32	55
1019	1·35	4·63	11·45	12·4	14·25	17·45	22·6	23·7	26·5	15	17	3+16	3+15	116	♂ ii	1+34	57
1020	1·57	4·7	11·2	12·4	14·0	17·35	22·3	23·45	25·9	15	18	3+15	3+14	143	♂ vi	†1+32	56
1021	1·5	4·6	11·3	12·35	14·2	16·95	22·25	23·55	26·15	14	16	3+16	3+14	143	♂ vi	0+32	55
1022	1·6	4·8	11·95	12·45	14·7	17·3	22·9	24·1	26·8	12+0+2	16	3+16	3+15	160	♂ v	2+31	55
1023	1·5	4·56	11·35	12·25	14·3	17·4	22·3	23·5	26·2	15	16	3+17	3+15	143	♀ v–vi	2+31	56
1024	1·48	4·66	11·95	12·8	15·1	17·65	23·1	24·5	27·35	15	17	3+17	3+14	166	♀ vi	2+32	56
1025	1·5	4·6	11·75	12·15	14·6	16·9	22·05	23·3	25·8	16	18	3+16	4+15	148	♂ vi	1+32	56
1026	1·46	4·74	11·75	12·2	14·65	17·5	22·9	24·15	26·9	16	17	3+17	3+16	143	♀ v	2+33	56
1027	1·48	4·47	11·9	12·6	14·5	17·65	22·8	24·1	26·6	15	16	3+15	3+15	150	♂ v–vi	2+32	56
1028	1·45	4·58	11·35	12·45	14·2	17·15	22·5	23·7	26·3	14	17	3+16	3+16	124	♀ vii	†0+33	56
1029	1·55	4·9	11·75	12·6	14·9	17·55	23·05	24·35	27·15	14	17	3+17	3+15	150	♂ vi	0+33	56
1030	1·37	4·47	11·0	12·1	13·8	16·8	21·8	23·0	25·6	14	18	3+17	3+14	132	♂ vi	1+32	56
1031	1·34	4·27	10·8	11·8	13·55	16·65	21·4	22·5	24·85	15	16	3+16	3+14	121	♂ vi	1+32	56
1032	1·4	4·43	11·65	12·5	14·55	17·2	22·5	23·75	26·35	14	16	3+16	3+14	158	♂ v–vi	1+32	56
1033	1·5	4·86	12·15	13·05	14·8	18·1	23·2	24·45	27·3	15	17	3+15	3+14	140	♂ vi	1+32	56
1034	1·3	4·4	11·15	12·3	13·9	17·1	22·2	23·4	26·2	15	16	3+16	3+14	143	v–vi	2+32	56
1035	1·5	4·78	11·9	13·0	15·0	17·75	23·3	24·6	27·3	15	16	3+16	3+14	146	vi–iv	2+32	56
1036	1·48	4·3	10·9	11·9	13·6	16·3	21·0	22·2	24·75	15	17	3+15	3+14	129	v	†0+33	56
1037	1·43	4·4	10·4	11·6	13·05	15·9	20·9	22·0	24·5	14	17	3+16	4+13	111	♂ vi	1+32	55
1038	1·4	4·3	10·3	11·0	12·7	15·5	20·3	21·3	23·6	16	17	3+15	3+14	108	vi	0+34	57
1039	1·43	4·78	11·5	12·6	14·35	17·4	22·4	23·65	26·35	15	16	3+17	4+13	145	♂ v	†1+32	56
1040	1·45	4·3	11·4	12·5	14·1	17·25	22·45	23·65	26·3	14	17	3+16	3+15	154	vi	0+33	56
1041	1·62	5·0	11·85	12·6	14·85	17·9	22·9	24·2	26·7	15	17	3+16	3+13	136	♀ vi–iii	1+32	56
1042	1·5	4·8	12·1	12·8	14·9	18·05	23·2	24·5	27·05	16	17	3+16	3+14	144	♂ vi	1+33	56
1043	1·67	5·15	12·5	12·95	15·45	18·1	23·9	25·2	28·2	15	17	3+17	3+15	153	vii	1+33	57
1044	1·6	5·07	12·65	13·2	15·75	18·75	24·4	25·8	28·6	16	17	3+16	3+13	159	vi–iii	3+31	57
1045	1·62	4·9	11·85	12·5	14·6	17·55	22·45	23·85	26·65	14	17	3+16	3+16	175	♂ v–vi	0+32	55
1046	1·56	4·8	12·55	13·3	15·65	18·75	24·15	25·33	28·3	14	16	3+17	3+14	173	v	0+33	55
1047	1·53	4·85	12·1	12·4	15·05	17·6	22·95	24·2	26·9	15	18	3+17	3+14	153	iv–v	0+33	56
1048	1·45	4·3	10·5	11·35	13·2	16·05	21·05	22·3	25·0	15	17	3+16	3+15	130	♂ vi	2+31	55
1049	1·3	4·18	10·75	11·5	13·35	16·15	20·95	22·0	24·45	15	17	3+16	3+14	116	♂ vi	1+32	56
1050	1·67	4·87	11·8	12·85	14·6	17·7	22·7	23·95	26·95	14	16	2+16	3+14	171	♂ v–vi	3+30	56
1051	1·67	5·1	11·95	12·7	14·8	17·8	23·05	24·3	27·05	14	18	3+16	3+14	158	♂ v–vi	3+31	55
1052	1·4	4·6	11·75	12·35	14·2	17·1	22·6	23·7	26·2	15	17	3+15	2+15	134	♂ vi–iii	0+33	56
1053	1·42	4·47	11·5	12·25	14·4	17·0	22·0	23·2	25·7	15	17	2+18	3+15	139	♂ v	1+31	57

1054	1·65	4·77	11·75	12·45	14·7	17·4	22·7	23·95	26·7	15	17	3+17	3+14	161	♂ v	1+32	55
1055	1·53	4·78	12·35	13·35	15·25	18·45	23·95	25·15	27·95	14	17	3+15	3+14	192	♀ v	†0+33	56
1056	1·66	4·98	12·05	13·4	15·05	17·9	23·25	24·55	27·25	14	16	3+17	3+14	163	♀ vi	1+32	56
1057	1·4	4·3	10·9	11·7	13·5	16·15	21·35	22·5	25·05	14	17	3+17	3+14	129	♂ vi	2+31	56
1058	1·57	4·65	11·2	12·05	14·0	16·7	22·0	23·1	25·85	14	17	3+17	3+14	136	♀ v	2+31	55
1059	1·53	4·57	11·5	12·05	14·3	17·15	22·55	23·75	26·45	14	17	3+16	3+16	171	♂ v	1+32	55
1060	1·47	4·5	11·55	12·2	14·25	17·15	22·3	23·55	26·25	14	16	3+16	3+14	144	♀ vi	1+32	55
1061	1·4	4·48	11·4	11·75	14·25	17·0	22·15	23·35	25·85	15	18	3+16	3+13	134	♀ v	0+32	56
1062	1·57	4·6	11·0	11·3	13·85	15·95	21·0	22·2	24·6	14	17	2+17	4+13	128	♂ v–vi	2+33	56
1063	1·5	4·93	12·2	13·3	15·0	18·05	23·5	24·8	27·6	13	16	3+16	3+15	146	♂ vi	2+32	56
1064	1·6	4·8	11·8	12·2	14·5	17·3	22·6	23·8	26·2	13	16	3+17	4+15	139	♀ vi	1+[1+1*+30]	55
1065	1·55	4·62	11·15	12·2	14·3	17·05	22·25	23·5	26·15	15	16	3+17	3+15	152	♀ vi	1+32	56
1066	1·43	4·4	11·05	11·9	14·05	16·95	21·9	23·0	25·5	15	16	3+17	3+14	116	♂ vi–iii	1+32	56
1067	1·7	5·08	12·5	13·2	15·5	18·6	23·85	25·2	28·1	14	16	3+17	3+14	154	♂ iv–v	3+31	56*
1068	1·54	4·6	11·35	12·45	14·35	17·1	22·1	23·3	25·75	14	15	3+16	3+14	129	♀ vi–iv	0+33	56
1069	1·5	4·44	10·45	11·1	13·0	15·75	20·6	21·7	24·2	14	16	3+16	3+15	113	♀ vii	1+31	54
1070	1·42	4·37	10·95	11·35	13·4	16·2	21·1	22·2	24·55	16	17	3+16	3+14	129	♂ vi	†2+31	56
1071	1·45	4·2	10·3	10·85	12·7	15·45	20·2	21·25	23·75	15	16	3+16	3+15	117	♂ vi	1+31	54
1072	1·7	5·1	12·7	13·7	15·8	18·8	24·2	25·63	28·65	15	16	3+16	2+15	182	♀ vi	1+32	56
1073	1·3	4·2	10·6	11·35	13·3	15·9	20·9	22·05	24·6	14	17	3+16	2+15	127	♂ v–vi	0+33	55
1074	1·5	4·72	11·7	12·35	14·45	17·5	22·6	23·85	26·6	15	16	3+16	2+14	121	♂ ii	3+31	56
1075	1·47	4·7	11·8	12·55	14·45	17·7	22·55	23·75	26·55	15	16	3+15	3+14	147	♂ v	†0+32*	55

APPENDIX TO TABLES.

† This sign in all cases indicates that no lateral processes are present in the vertebræ immediately preceding the 1st vertebra with complete hæmal arch or the most anterior incomplete arch denoted in the records. The processes in these cases have been cleaned away.

* This sign *on the measurements* (Columns 1 to 9) indicates that the character is slightly abnormal in some way or that the part measured is slightly damaged. In columns 17 and 18 the asterisks refer to the following:—

Sample III.

Fish No.

3 * 12th vertebra with complete hæmal arch has two pairs of hæmal arches, but only one extra neural process on the right, which is attached to the 11th neural arch. The vertebra itself is slightly longer than adjacent ones, but has been counted as and appears to be only one. The left hæmal process of the 15th vertebra with complete hæmal arch is attached to the 14th hæmal arch and its fellow is free. The hæmal processes of the next vertebra, the 16th, are also free.

9 * Right portion of 11 and 12 hæmal arches fused with left division of 11th hæmal spine. 12th, left portion of hæmal arch free.

34 * 19th vertebra is very long and carries two pairs of neural and hæmal arches, the extra arches arising from the middle. It is recorded as one, but is apparently made up of two fused.

98 * 9th and 10th vertebræ (with complete hæmal arch) have each two pairs of neural spines, the 10th has also two pairs of hæmal spines, the abnormal pair having one limb (the left) arising from the middle of the centrum, but the other arising near the origin of the right member of the 11th hæmal arch. These vertebræ are each recorded as one; they are of normal size, and neither appears to be composed of two vertebræ fused, as is undoubtedly the case in other skeletons.

125 * 2nd vertebra with well-developed ventrolateral processes (paired).

139 * 6th hæmal arch with extra spine arising from junction of processes.

157 * Processes missing almost entirely one side and entirely on other side.

161 * Anterior group of vertebræ lost.

241 * 1st hæmal arch has a supernumerary hæmal process in the middle of the vertebra on the left side.

243 * 1st hæmal arch broken, but still attached to vertebra.

267 * Incomplete arch, although nearly complete. The vertebra preceding had a complete hæmal arch as noted in the record.

270 * Transverse bars nearly joined. The right-hand figure of Fig. 3 is drawn from this vertebra.

277 * 10th and 11th hæmal arches are joined by a bony cross-piece.

288 * 14th and 15th vertebræ have each two pairs of hæmal spines, the subsidiary pair being in the middle, but only the 14th pair has also a corresponding neural arch.

291 * 19th neural spines quite free.

299 * 24th hæmal spines free ; no loop formed.

310 * 5th neural spines are separate, and there is an extra free neural spine on the right, and the 5th, 7th, and 8th hæmal arch processes are bifurcated at the tip, and three of the 7th are not joined together at all, that is both spines are free.

316 * 15th and 16th left rays of hæmal arches are joined up with the 15th right hæmal arch ray. The 16th right ray is free.

351 * In the case of high numbers as 33 and 34 the first hæmal arch is generally without the lateral processes.

352 * 11th hæmal arch, processes not fused, and right one bifurcated.

401 * Atlas with pair of well-developed dorso-lateral spines.

416 * Extra spine on 16th hæmal arch, arising from junction of processes of arch.

427 * Last vertebra but two is peculiar, being unusually small, and being somewhat fenestrated on the left side but normal on the right side. Otherwise the skeleton is quite normal.

435 * The eleventh vertebra bears on the left a hæmal spine showing a slight bifurcation at the tip ; the hæmal spines in the anterior region in this fish were very well developed.

453 * 1st arch broken, but still attached to vertebra.

462 * Less well developed than processes of anterior vertebra.

529 * The last vertebra but two is apparently made up of two fused, being almost twice as long as adjacent ones ; it bears two pairs of hæmal and neural spines, but has only an anterior and posterior articulation; the centre is distinctly fused. This is only counted as one.

546 * 1st vertebra with complete hæmal arch has a supernumerary hæmal process on the left side, and the 14th vertebra with complete hæmal arch has a supernumerary pair of hæmal and neural spines arising from middle of vertebra ; both pairs of hæmal spines are joined by a cross-piece on the right side.

Sample IV.

552 * 1st hæmal arch broken off centrum, but still attached.

580 * Extra spine from junction of hæmal spines of 23rd vertebra from posterior end.

582 * On some posterior hæmal arches are spherical concretions which appear like little beads of melted metal. This phenomenon has been noticed on other skeletons also.

588 * Atlas, 1st, and axis, 2nd, vertebræ fused together ; counted as two.

631 * This one incomplete, but with an internal process on the right hæmal process. The arch of the vertebra anterior to it is complete.

664 * 7th vertebra from posterior end has two pairs of hæmal and neural spines, is longer than normal and apparently equal to two fused vertebræ. It is counted, however, as one.

667 * 4th, 5th, and 6th vertebræ from posterior end have been broken and recovered at some period of life of the fish.

687 * The last vertebra bears three pairs of neural and two pairs of hæmal spines, it is nearly twice as long as a normal one, and has a thickening in the middle of the centrum where apparently two vertebræ have fused. It is undoubtedly two vertebræ fused. It is, however, only counted as one in the table.

709 * 3rd complete arch has a tiny extra connecting hæmal process on the left.

711 * Middle tips of hæmal arches with curious concretionary appearance, just as though the arches were of metal and had been melted in parts.

740 * The right hæmal process of 28th vertebra is joined to junction of hæmal processes of 27th vertebra ; the left process of the 28th vertebra being free.

746 * 13th vertebra from anterior end is about half as long again as normal, and has ridges around its middle indicating fusion of two vertebræ. It is, however, counted as one.

There is no normal articulation in the middle, but complete fusion.

767 * 9th vertebra very long and apparently two vertebræ fused, similar to 704. It is counted, however, as one.

782 * It is quite possible that one or more arches are missing here ; possibly too well cleaned.

784 * Arch incomplete, though the one anterior to it is complete (broken, but still attached to centrum).

803 * 1st hæmal arch broken, but still attached to vertebra.

841 * There is nothing unusual in the appearance of this skeleton.

843 * 1st hæmal arch with a rib attached.

855 * 2nd, 3rd, 4th, 5th, and 6th rays of anal fin anastomising.

897 * In the region two-thirds from anterior end the hæmal and neural arches arise from abnormal positions and there are a few extra spines.

899 * Several hæmal arches with processes interchanged, i.e. processes on opposite sides not joined up with fellow, but with those anterior or posterior to them.

911 * 3rd hæmal arch broken, but was undoubtedly complete.

921 * 46th vertebra from anterior end, 3 pairs of hæmal and $2\frac{1}{2}$ pairs of neural spines. The centrum is abnormally long, nearly twice normal length, and is apparently equal to at least 2 vertebræ fused. It is counted as one.

925 * In Character 17 the "*a*" portion is recorded hence first in order to avoid any bias towards making up the number to the apparent total of 33 or 34 potential arches.

943 * 35th vertebra with two pairs of neural and hæmal spines, nearly twice as long as normal, and apparently equals two fused. Counted as one.

962 * Arches about middle of skeleton a little abnormal.

975 * 12th vertebra nearly twice as long as normal, and apparently equal to two fused, but only counted as one. Also 30th vertebra with $1\frac{1}{2}$ hæmal arches and spines, but otherwise of normal size. 32nd also with abnormal hæmal arch processes.

980 * 39th vertebra with one hæmal arch attached to arch of 38th vertebra.

1010 * 37th vertebra has one extra neural and one extra hæmal spine, but is otherwise normal.

1064 * Vertebra behind 1st complete arch carries an incomplete but well-developed arch ; it is counted with those having complete arch.

1067 * Left process of 44th hæmal arch is joined up with junction of 43rd hæmal arch.

1075 * 1st hæmal arch broken, but still attached to centrum.

Note.—The lateral processes of the vertebræ preceding those with complete hæmal arch are sometimes long without internal processes, and at other times shorter with the internal process developing. Nevertheless, the arbitrary character chosen has been adhered to as closely as possible. There are, however, doubtful cases.

Very frequently the 4th, 5th, and 6th vertebræ from posterior end have the base of the hæmal arch passing diagonally across the ventral anterior half of the centrum, and in this respect are unlike the other vertebræ.

On the Amount of Phosphoric Acid in the Sea-Water off Plymouth Sound.

By

Donald J. Matthews.

In spite of its biological importance, only a few investigators have turned their attention to the content of the sea in phosphoric acid. The older analyses by C. Schmidt (1) and Forchammer are quoted by K. Brandt (2). Schmidt found from 2·8 mg. to 5·5 mg. of P_2O_5 per 1000 grms. of water in the colder seas, and from 0·76 mg. to 1·8 mg. in warmer regions, while Forchammer found from 4·6 mg. to 12·5 mg. in the Gulf of Finland. Krümmel (4) refers to these as inaccurate, and quotes the results of analyses made much more recently by E. Raben, in connection with the International Fishery Investigations, as alone reliable. K. Brandt (3) also refers to Raben's work in various papers, but neither the present writer nor Professor Martin Knudsen, of Copenhagen, who has very kindly made a search also, has been able to find any original paper by Raben on the subject, so that we unfortunately know nothing of his methods beyond the fact, given by Brandt, that the samples were filtered immediately after collection through Schleicher and Schull's hardened paper. This is a very necessary precaution, as there would be danger of an increase in the phosphates owing to the decomposition of suspended organic matter by bacteria. The present writer has found that even a filtered sample cannot be put aside in safety for any length of time unless previously sterilised, as the whole of the phosphoric acid may be removed by the growth of moulds.

Krümmel mentions also some analyses by Sir John Murray as equally defective.

Raben's samples were collected in the Baltic and North Sea ; he found as a rule less than one milligram of P_2O_5 per litre, with a minimum of 0·14 mg. to 0·25 mg. in February and May, and a maximum of 1·46 mg. in the autumn.

The present writer, in sea-water taken half a mile outside the Breakwater at Plymouth, has found as a maximum 0·1 mg. per litre, less than the lowest result given by any of the workers mentioned above.

The determination of phosphoric acid in sea-water falls into two parts, first concentration in small bulk, and then determination of the amount. Concentration may be effected either by precipitating, by the addition of ammonia, a portion of the alkaline earths, which carries down the phosphoric acid, or by adding an iron salt, ammonium chloride, and ammonia and precipitating a mixture of ferric phosphate and hydroxide. The estimation may be carried out either gravimetrically as ammonium phospho-molybdate, or colorimetrically by the very sensitive reaction with nitro-molybdate of strychnine described by Pouget and Chouchak (5). The writer finally adopted the colorimetric method following concentration with iron, but all four processes have been used.

From April 21 to September 13, 1915, the method was as follows: About 1500 ccm. of filtered water was precipitated, after making slightly acid and heating, with iron and ammonium chloride and ammonia. The precipitate was filtered off, dissolved in warm dilute nitric acid, and evaporated to dryness several times with further addition of acid to remove silica. The phosphorus was determined by precipitating with ammonium molybdate and weighing as anhydride. For such small quantities, the amount of anhydride being only a few milligrams, the method cannot be considered satisfactory, as there is danger of loss through some of the precipitate dissolving in the wash-waters or being carried through the asbestos of the Gooch crucible, and on the other hand there is the risk of the results being too high owing to the simultaneous precipitation of a trace of molybdic acid. With one exception the figures obtained were much higher than most of those by the colorimetric method. From April 21 to July 14 about 0·07 mg. per litre was found gravimetrically; there was then a break in the series and the next analysis, made on September 13, showed a considerable fall to 0·04 mg. by the gravimetric method, in good agreement with that for September 21, when 0·046 mg. was found by the colorimetric method, which was adopted for all following work.

Samples for the colorimetric method were at first concentrated by precipitating 500 ccm. of filtered sea-water with 3 ccm. of pure concentrated ammonia, heating, and filtering off the voluminous precipitate of hydroxides, dissolving it in nitric acid, and evaporating on the water-bath to dryness, after which it was treated as described later. The method had the advantage that only one reagent was used for precipitation, and as a rule the solution filtered quickly and duplicate analyses agreed well, the average difference being 0·0029 mg. per litre. Its accuracy, however, was difficult to establish without making up an artificial sea-water free, or nearly so, from phosphates, and this was found to be impossible with the purest chemicals of Merck and Kahlbaum. As an example, the artificial sea-water was found to contain 0·0143 mg. of P_2O_5 in 500 ccm.; 0·0234 mg. was added to 500 ccm. and 0·0328 mg. found, a loss of 0·0049 mg. In another experiment made on 250 ccm. the loss was only 0·0007 mg. These differences are both of about the same magnitude as those found between duplicate analyses of sea-water, so the experiments are not conclusive, though it shows that the method is at any rate approximately accurate. Comparison was also made with the method finally used; simple precipitation by ammonia gave 0·0312 mg. per litre, against 0·0318 mg. and 0·0316 mg. by the final method. Again, precipitation by ammonia gave 0·057 mg. in duplicate analyses; treatment of the filtrate from one of these by ammonia gave a further voluminous precipitate which contained no recognisable phosphates. The method is therefore probably accurate to about 0·003 mg.

In the end, concentration by iron was found to be the most satisfactory and quickest method, duplicate determinations taking five hours or less when the water had been previously filtered. The requisites are :—

Ferric nitrate or chloride solution, nearly neutral, containing 5 to 6 mg. of iron in 1 ccm.

Nitric acid, strong and 25 per cent by volume.

Ammonia, dilute; 2 N is a convenient strength.

Ammonium chloride; about 2 N.

Pouget and Chouchak's reagent; two solutions are required. A: 95 grms. of molybdic acid and 30 grms. of anhydrous carbonate of soda are dissolved in 500–600 ccm. of warm water, and after cooling 141 ccm. of strong nitric acid are added. The solution is made up to 1000 ccm. B: a 2 per cent solution of strychnine sulphate. For use 1 ccm. of B is added to 10 ccm. of A and the mixture filtered and used at once. With 0·03 mg. of P_2O_5 in 50 ccm. of 3·7 per cent nitric acid, this reagent gives a strong opalescence at once, while 0·005 mg. will give the reaction in a few minutes. This opalescence is yellow when examined in the colorimeter; it takes twenty minutes to attain its full strength, and after three or four hours a precipitate is thrown down, so the comparisons should be made as soon as possible after the twenty minutes have elapsed. The colour is proportional to the amount of phosphoric acid when the content in P_2O_5 lies between 0·01 mg. and 0·05 mg. in 50 ccm.; it is affected by variations in the amount of reagent used and by the amount of free nitric acid. Pouget and Chouchak give a number of determinations in the presence of various oxides, and show that the results are very good unless the oxides are present in very large amount; for instance, lime is without influence when there is not more present than 20,000 times the weight of the phosphorus pentoxide, while iron should not exceed 1200 times its weight. They recommend also that for the greatest accuracy two standard solutions should be made up, one containing 0·03 mg. P_2O_5 for use with samples containing this amount or more, and another containing 0·02 mg. for samples containing less than 0·03 mg.

Colorimeter. The writer has used the Dubosq pattern with comparison tubes 5 cm. in height and a swinging shade in front to cut off side light. For the comparison of phosphorus samples the model with 10 cm. tubes would probably have been better.

Filter papers should be washed with dilute nitric acid and hot water. The writer has found traces of phosphoric acid in two of the best-known hydrofluoric-acid washed papers.

Porcelain and *glass* should be tested before use by extraction with hot dilute nitric acid and dilute ammonia. There are some varieties which will give up several milligrams of P_2O_5 during an analysis.

India-rubber should not be allowed to come in contact with the acid or alkaline solutions.

The analyses have been carried out as follows: The samples were taken in glass-stoppered "Winchester quart" bottles, holding about 2700 ccm. As they were collected so near to the Laboratory it was generally possible to begin the filtration within three hours, so that there was no necessity for sterilisation. Filtration was carried out by replacing the glass stopper by one of rubber through which passed two glass tubes, which projected about 6 mm. on the inner side; outside the bottle one projected about 25 or 30 mm., the other a few millimetres less. The bottle, full to the stopper, was quickly inverted on a retort ring with the tubes projecting into the filtering funnel below the upper edge of the filter paper. Filtration then goes on without attention; as a rule it was started in the afternoon and was finished by the following morning. Double papers were always used, sometimes Schleicher and Schull, No. 589, "black band" inside, to catch the coarser particles, with a "blue band" outside; at other times Whatman's papers, No. 1 or No. 40. If there is much sediment No. 40 is almost too slow; one sample took thirty-six hours to filter.

As a rule 500 ccm. was taken. The water was measured into a hard glass beaker, and 10 ccm. of 2 N ammonium chloride and 1 ccm. of the iron mixture were added, with a few drops of dilute nitric acid to dissolve the precipitate. The mixture was heated to 70° or 80° C. on the water-bath and precipitated with the smallest possible quantity of dilute ammonia; the heating was continued until the precipitate had collected together, when it was filtered on a small washed paper and washed twice with hot water. The precipitate on the filter and adhering to the beaker was dissolved in warm dilute nitric acid and evaporated to dryness on the water-bath to remove silica. Seven cubic centimetres of 25% HNO_3 and 20 ccm. of water were added, the dish covered, and the solution heated for twenty minutes, when it was transferred to a 50 ccm. graduated flask. If there is much insoluble residue the solution should be filtered. The bulk was then made up to about 47 ccm., leaving space for 2 ccm. of reagent. The standards were prepared by making up the requisite amounts of P_2O_5 to about 47 ccm. with 7 ccm. of 25% HNO_3 and water; the writer has generally diluted the $\frac{1}{15}$-molecular phosphate solutions used in determining hydrogen-ion concentrations by the Sorensen method. Two cubic centimetres of the strychnine-molybdate reagent were then added to each flask, the bulk completed to the mark, and the whole well shaken. In twenty minutes the solutions are ready for comparison.

The writer has never been able to secure perfect equality of illumination in the two halves of the field of the colorimeter owing to the shape and setting of the window in the Laboratory, so the precaution was always taken of reversing the position of the tubes after six readings and then taking another six. The accuracy with which the readings could be made varied very much. On some days a set of six have been obtained which did not differ by more than 0·2 mm. on 40 mm., while at other times the uncertainty was from five to ten times as great. A large sheet of ground glass between the colorimeter and the window was often of great assistance. Comparisons by artificial light were very difficult and fatiguing, but the results were satisfactory.

To test the accuracy of the method the following experiments were made :—

Part of a standard, containing 0·0237 mg., was analysed against itself. In two experiments the results were too low by 0·0005 mg. and 0·0004 mg.

Three lots of 500 ccm. each of distilled water, to which 0·0237 mg. had been added, were analysed ; the errors were, +0·0010 mg., +0·0041 mg., and +0·0001 mg. From another 500 ccm., to which no phosphate had been added, 0·0036 mg. was obtained. The filtrate from this was acidified and analysed again without adding any more ammonium chloride. The amount found was again 0·0036 mg. This value was taken as the blank instead of the mean, 0·0025 mg. The result in which an excess of 0·0001 mg. was found was probably erroneous owing to the evaporation having been carried out on the sand-bath, which might give rise to overheating and formation of pyrophosphates. An artificial sea-water was made up and found to contain 0·0100 mg. To this was added 0·0150 mg., and analysis showed a loss of 0·0008 mg. The result is not conclusive as the blank on the sea-water was so high.

To test the effect of varying bulk, two lots of natural sea-water were examined, one in its natural state, the other after evaporation to small bulk. The amounts found were 0·0318 mg. and 0·0316 mg. respectively. A third portion, precipitated by strong ammonia only, gave 0·0312 mg.

Filtrates from the iron precipitate were also examined. The amount found by analysis of two lots of a sea-water were 0·0378 mg. and 0·0391 mg. To one filtrate 0·0237 mg. was added and 0·0266 mg. found, a gain of 0·0029 mg. No more phosphate was added to the other and 0·0025 mg. was found, using a very dilute standard. In another experiment the figures for the original analyses were 0·0336 mg. and 0·0348 mg. ; 0·0237 mg. was added to each filtrate and gains of 0·0013 mg. and 0·003 mg. were obtained. These gains are all small, the average being 0·0018 mg., half the blank on the reagents. Finally the filtrate from the sample mentioned above as having been concentrated to small bulk was examined after the addition of 0·0237 mg. The gain in this case was higher, 0·0058 mg.

The fact that the errors on the filtrates, though small, were all positive, made it seem possible that there was still phosphorus, though not necessarily phosphoric acid, unprecipitated. To test this three lots of 500 ccm. were taken ; two were analysed in their natural condition, giving 0·0336 mg. and 0·0348 mg. The third portion was boiled for three-quarters of an hour with 10 ccm. of decinormal potassium permanganate in Jena glass ; it was then acidified with HCl. and boiled for two hours longer. On analysis 0·0558 mg. was found, a gain of 0·0216 mg. Another sea-water gave 0·0415 mg. and 0·0566 mg. for the natural and oxidised portions, a gain of 0·0147 mg. The filtrate from the oxidised portion was analysed without the addition of more phosphoric acid and 0·0018 mg. found. A similar experiment made earlier by the gravimetric method showed an increase from 0·082 mg. to 0·147 mg. on oxidation. In one case an untreated water was found to contain 0·09 mg. by the gravimetric method ; the filtrate was oxidised and yielded a further 0·07 mg

There are two possible explanations of this increase of the phosphates by oxidation. One is that there may be in sea-water a small quantity of organic matter which hinders but does not completely prevent the separation of the phosphoric acid by iron ; the objection to this is that the action would probably be irregular and the duplicate analyses would differ more widely than they do. The other, to which the writer inclines, is that there is a considerable amount of phosphorus present in forms other than phosphoric acid, perhaps as phosphites or as an organic compound, which is oxidised to phosphoric acid by potassium permanganate.

The ratio of phosphoric acid found in the untreated sample to the total shows a tendency to constancy, but it has not been determined yet whether the permanganate method converts the whole of the phosphorus into phosphoric acid, and experiments on this are in progress.

The samples of sea-water, with two exceptions, were taken at the Knap Buoy, half a mile outside the lighthouse on Plymouth Breakwater. The other two were taken close to the rocks under the Laboratory.

The results are given in the following table, and also the method by which they were obtained.

The salinity was determined against the *International Normal Water.*

SURFACE SAMPLES TAKEN AT THE KNAP BUOY.

Date.	G.M.T.	S. ‰	Method.	P_2O_5, mg. per litre.	
				Found in duplicates.	Mean.
1915					
April 21	10.30 a.m.	—	Iron and gravimetric	—	0·1
,, 23	—	—	,, ,,	—	0·1
June 21	10.30 a.m.	—	,, ,,	—	0·049
July 5	noon	—	,, ,,	—	0·064
,, 12	10.30 a.m.	—	,, ,,	—	0·09
,, 14	11.40 a.m.	34·83	,, ,,	—	0·082
Sept. 13	11.30 a.m.	34·92	,, ,,	—	0·04
,, 21	10.30 a.m.	34·96	Ammonia and colour	—	0·046
Nov. 24	11.35 a.m.	34·78	,, ,,	0·042, 0·041	0·0415
,, 26	11.45 a.m.	34·43	,, ,,	0·040, 0·034	0·037
,, 29	11.10 a.m.	34·14	,, ,,	0·040, 0·037	0·0385
Dec. 2	12.20 p.m.	—	,, ,,	0·0484, 0·0435	0·0460
,, 9	10.30 a.m.	31·46	,, ,,	0·049, 0·047	0·048
,, 13	11.30 a.m.	—	,, ,,	0·044, 0·041	0·0425
,, 16	12.10 p.m.	26·20	,, ,,	—	0·043
,, 20	11.25 a.m.	29·69	,, ,,	0·058, 0·064	0·061
1916					
Jan. 3	11.35 a.m.	25·66	,, ,,	0·057, 0·057	0·057
,, 14	1.55 p.m.	33·87	Iron and colour	0·0318, 0·0316	0·0317
,, 18	2.30 p.m.	33·93	,, ,,	0·0336, 0·0348	0·0342
,, 24	11.20 a.m.	33·42	,, ,,	0·0378, 0·0391	0·0384
Feb. 5	12.30 p.m.	31·58	,, ,,	0·0507, 0·0414	0·0460

SURFACE SAMPLES TAKEN UNDER LABORATORY.

1916					
Jan. 17	—	—	Iron and colour	0·0602, 0·0572	0·0587
Feb. 11	—	—	,, ,,	0·0408, 0·0421	0·0414

A few points come out clearly from the results.

In the first place, the results are much lower than those obtained by Raben for the Baltic and North Sea, his lowest being 0·14 mg. per litre against 0·1 mg., the highest found at Plymouth. The salinity at the Knap Buoy is nominally 33·5 per thousand up to nearly 35, comparable with a large part of the North Sea. But the North Sea receives enough fresh water from the great rivers of Russia and Germany to keep the salinity of nearly the whole of it below 35 per thousand, while the effect of the land drainage in the western part of the English Channel is confined to a comparatively narrow band along the coast. The effect of an increased supply of land water in increasing the phosphoric acid is seen in the results for December 20 and January 3, when the salinity was very low; a sudden rise occurred then after the figures had been fairly constant for two months or more. This rise did not show itself till a few days after the salinity had fallen, which suggests that much of the phosphorus from the land enters the sea in an incompletely oxidised form and is then converted, by bacterial action, into phosphoric acid.

If the earlier gravimetric results are taken as correct there is a decided seasonal change, the higher values being found in spring and summer, but the writer is not inclined to place much confidence in them. The experiments are being continued and it is hoped that the next few months will settle the question.

It is unfortunate that so far it has not been possible to obtain samples at a greater distance from shore, as it may be that the increased phosphoric acid found after oxidation is a purely littoral or estuarine phenomenon resulting from the form in which part of the phosphoric acid is carried down by land-water. It does not seem likely that it arises from diatoms or bacteria which pass through a paper filter, as the same increase was noticed on oxidising a filtrate from a solution in which iron had been precipitated by ammonia, a very efficient method of removing the finest suspended particles. The approximately constant ratio of the two forms of phosphorus is also an objection to this explanation.

SUMMARY.

1. Phosphoric acid in sea-water may be determined with an accuracy of about 0·003 mg. per litre by concentration with iron and colorimetric examination.

2. If the sea-water be previously oxidised by potassium permanganate the amount found is considerably increased.

3. From September, 1915, to February, 1916, the average amount of phosphoric acid in water collected half a mile outside Plymouth Break-

water was 0·044 mg. per litre; this showed signs of an increase when the supply of land-water rose after rain. The figures are much lower than those found by Raben for the Baltic and North Sea.

4. The amounts found by another method during the previous spring and summer are higher, but the figures cannot be considered quite trustworthy.

Note.—Since the above was written, it has been found that boiling with potassium permanganate does not oxidise the whole of the phosphorus with certainty. Duplicate analyses of a sample taken on Jan. 17th, 1916, both gave 0·0190 mg. per litre. Two other portions were oxidised and found to contain 0·0449 mg. and 0·0569 mg. per litre.

An attempt has also been made to determine whether any of the phosphoric acid is reduced to other forms in the short interval between the collection of the water and the beginning of the analysis. A sample of water was sterilised with toluol immediately after taking. A single determination showed 0·0350 mg. per litre in the original sample, and 0·0375 mg. after oxidation. But the water for over a week had been extraordinarily clear and free from suspended matter, far more so than any of the samples given in the table, so that the experiment cannot be considered conclusive.

BIBLIOGRAPHY.

1. C. Schmidt.—Hydrologische Untersuchungen. Bull. Akad. Petersburg. Bd. 24, 1878. Quoted by Brandt.
2. K. Brandt.—Ueber den Stoffwechsel im Meere. 2 Abhandlung. Wiss. Meeresuntersuch. Kiel, 1902.
3. K. Brandt.—Untersuch. über den Gehalt des Meerwassers an spurenweise vertretenen Pflanzen-Nahrstoffen. Beteil. Deutschlands a.d. internat. Meeresforch. I, II and III Jahresbericht.
4. O. Krümmel.—Ozeanographie I, p. 323.
5. Pouget, I., and Chouchak, D.—Dosage colorimétrique de l'acide phosphorique. Bull. Soc. Chim. France. 4 series, V, 1909, p. 104, and IX, 1911, p. 649.

In Memoriam.

H. C. DANNEVIG, Director; G. W. C. PIM, Master; C. T. HARRISSON, Biologist; and eighteen others, comprising the crew of the Australian Fishery Investigation steamer *Endeavour*, who were lost at sea in December, 1914.

THE FEDERAL GOVERNMENT TRAWLER
"ENDEAVOUR"

The Department of Trade and Customs of the Commonwealth of Australia have issued a memorial number of their Report on Fisheries, giving particulars, as far as they are known, of the loss at sea of their investigation steamer *Endeavour*, with all on board, including the Commonwealth Director of Fisheries, Harald Christian Dannevig; the Biologist, Charles Turnbull Harrisson; the Captain, George William Charles Pim, and a crew of eighteen men. The ship left Macquarie Island on December 3rd, 1914, to return to Australia and was not heard of again. It is thought that she perished in a heavy gale which was experienced on the island two days after she had left.

The work carried out by Dannevig with the *Endeavour*—a steam trawler specially built for fishery investigations in Australian waters—is well known to all Marine Biologists, and ranks with the best work of the kind which has been accomplished anywhere. The sympathy of British naturalists will be extended to their Australian colleagues, as well as to the relatives and friends of those whom the sea has claimed, in the sad loss they have sustained.

PUBLICATIONS OF THE ASSOCIATION.

Journal of the Marine Biological Association.

OLD SERIES.

No. 1, AUGUST, 1887 (only a few copies left, reserved for Libraries).
No. 2, AUGUST, 1888. Price 1*s*.

NEW SERIES (*Royal* 8*vo*).

Volume I., 1889–90, 472 pp., 28 plates.
Volume II., 1891–2, 410 pp., 14 plates.
Volume III., 1893–4, xxxviii. and 458 pp., 5 plates and 25 woodcuts.
Volume IV., 1895–7, iv. and 425 pp.
Volume V., 1897–9, 550 pp. and 16 plates.
Volume VI., 1899–1903, 676 pp., 3 charts and 7 plates.
Volume VII., 1904–6, 508 pp., 1 chart and 12 plates.
Volume VIII., 1907–10, 519 pp. and 24 plates.
Volume IX., 1910–13, 619 pp. and 7 plates.
Volume X., 1913–15, 675 pp., 1 chart and 198 text figures.
Volume XI., No. 1.

Separate numbers (generally 4 to one volume), in wrappers, from 1*s*. to 5*s*. each. according to size.

London Agents: Messrs. DULAU & Co., LTD., 37 Soho Square, W.

Cloth 4to, 150 *pp.,* 18 *plates* (12 *coloured*).

A TREATISE ON THE COMMON SOLE.

BY

J. T. CUNNINGHAM, M.A., F.R.S.E.,
Late Fellow of University College, Oxford; Naturalist to the Association.

Medium 8vo, 368 *pages.* 159 *Illustrations and two Maps. Price 7s. 6d. net.*
(*Macmillan & Co., London.*)

THE NATURAL HISTORY OF THE MARKETABLE MARINE FISHES OF THE BRITISH ISLANDS.

Prepared expressly for the use of those interested in the Sea-fishing Industries.

BY

J. T. CUNNINGHAM, M.A.,

FORMERLY FELLOW OF UNIVERSITY COLLEGE, OXFORD;
NATURALIST ON THE STAFF OF THE MARINE BIOLOGICAL ASSOCIATION.

With Preface by

E. RAY LANKESTER, M.A., LL.D., F.R.S.,

PROFESSOR OF COMPARATIVE ANATOMY IN THE UNIVERSITY OF OXFORD.

The Microplankton of Plymouth Sound from the Region beyond the Breakwater.

By

Marie V. Lebour, M.Sc.,

Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist at the Plymouth Laboratory.

With Figures 1–9 in the text, and Tables I and II at the end.

THROUGHOUT a complete year from September, 1915, to September, 1916, sea-water samples were taken regularly two or three times a week from beyond the Breakwater in the region of the Knap buoy, 2½ miles from Plymouth shore, from the surface and at 5 and 7 fathoms. The object was to supplement the existing records from the tow nets as it is well known that a very large amount of material is lost even from the finest nets, as Lohmann has shown exhaustively (1908). So far the only plankton records from this region have been from the tow nets, and a glance at the tables given at the end of this paper will show directly, if compared with those by Gough (1903–7) and Bygrave (1911), also Cleve (1899 and 1900), the great difference in numbers of the smaller forms, or their entire absence from the tow nettings. Again, no actual numerical records have been given from this region. At the same time as the water samples were taken, tow nettings, coarse, medium and very fine, were also secured, and these were regularly examined for comparison.

The water samples were estimated by means of the centrifuge after the manner introduced by Lohmann. A water-bottle was used for the 5 and 7 fathom samples, and the surface sample was collected in a Winchester bottle. Experiment showed that there was no difference in the surface samples when collected either with the water-bottle or Winchester, and it was found more convenient for keeping as it was unnecessary always to examine it the day of collection, as was the case with the water-bottle samples. The Winchester samples keep for two or three days at a uniform temperature. If examined the day they are brought in the water-bottle samples are quite as good as the surface samples in the

Winchester for Peridiniales and Protozoa, which perhaps include the most delicate of all the plankton organisms. The samples were all examined fresh when possible; if impossible, which was only seldom, they were preserved by adding strong Flemming's solution at the time of capture as advised by Gran (1912*a*). For most species this method of preservation was found very satisfactory.

For quantitative estimation a certain amount (usually 50 cc.) of the sample water was put in tubes and centrifuged. Five tubes each holding 10 cc. were examined, the tubes pointed at the end after Lohmann's pattern, so that the contents may be emptied out and leave the residue in the point; this residue was removed carefully with a fine pipette, put on a ruled glass slide and the contents counted. The water was then re-centrifuged and the process gone through again. It was found that although re-centrifuging answered very well for diatoms, *Peridinium* and the more sturdy organisms, it was no use for the fragile forms such as the naked Peridiniales and small Infusoria, many of which are most probably destroyed even before they are brought in.

It was found by experiment that centrifuging for ten minutes gave the best results, the largest number of gymnodinians being secured in this way. This is longer than the time taken by Lohmann, but his centrifuge made many more revolutions than ours, the number of ours not being exactly estimated.

The tow nettings were not exhaustively examined, but the most important organisms were noted and their relative abundance. The nets used were of silk with meshes 26, 50 and 150 to the inch respectively, mouth 56 inches in circumference (inside), and bottom 15 inches in circumference. Length of silk clear of the calico to which it is attached at the ends, 39 inches. Area of silk, 1382 inches. Duration of haul, 10 to 15 minutes, or in exceptional cases a few minutes longer.

The following quick method was adopted: anything large first noted with the naked eye, then a certain amount of each sample taken, and when 30 or more of any organism was present it was marked cc; if 20 but under 30, c; if 6 but under 20, +; if more than one but under 6, r; if only a single specimen rr. In this way a rough estimate of what is common in the tow nets is made. In the case of the very fine samples after stirring two separate drops with a pipette are examined and the above method applied.

On the few days when it was impossible to go beyond the Breakwater the samples and tow nettings were taken from the west channel at the side of the Breakwater. For a fortnight in April it was impossible owing to the storms to go out at all. After this, about the 25th, the increase in plankton is large. The samples were as nearly as possible taken at the same time of day, between 11 a.m. and 1 p.m., and the state of tide, wind, and weather noted.

A great many species get through the meshes of even the finest nets. Those which are nearly always lost are the smaller Peridiniales, especially the *Gymnodiniaceæ*, the small Infusoria, with the exception of the *Tintinnoidea*, small flagellates (very few of which, however, appeared in our samples), Protozoa of various kinds and many of the smaller diatoms. On looking through the Plymouth records in the Fisheries Investigations we find an almost complete absence of all the very small Peridiniales, and with one exception (that of *Gymnodinium lunula*, which owing to its large size is conspicuous) an absolutely complete absence of *Gymnodiniaceæ* which confirms Lohmann's statement that all were lost. *Prorocentrum micans* is almost absent from the tow nettings, here again in agreement with Lohmann, who found a large loss. Infusoria, except the *Tintinnoidea* are practically absent, and among the diatoms we find records of species such as *Chætoceras curvisetum*, which we have found *the* commonest species of this genus in the plankton, only represented at the most by the sign +, usually r or rr. At times it has appeared with us in quantity in the tow nets, but not nearly as frequently as in the water samples. *Paralia sulcata* is seldom to be found in the nets but is abundant in the water samples, and present nearly all the year round. In Gough's lists it is usually marked r or rr, never by either Bygrave or Gough is it marked cc.

Skeletonema costatum is another good example and one specially marked by Lohmann. Although sometimes recorded as cc for Plymouth, the few times it is thus marked bear no comparison with the numbers really contained in the water. This is a particularly abundant species here, and at Kiel it is shown to be in enormous numbers, most of which escape the net. The species of *Nitzschia* are also good examples, *N. closterium* and *N. delicatissima* particularly nearly always being lost by the net.

On the other hand, a good many of the larger species do not get into the water samples in anything like a representative number. For instance, the genus *Biddulphia* only appears very occasionally, when really it forms a most important part of the plankton at a certain season of the year. *Streptotheca thamensis* is another case; this species being very abundant at times in the tow nettings and only occurring in small numbers in the water samples. The genus *Rhizosolenia*, although the relative abundance of the species is usually well shown in the water samples, is yet sometimes very ineffectually represented. For instance, in June *Rhizosolenia Shrubsolei* appeared in all the tow nets for two or three days, particularly on June 19th, especially in the medium net, and the specimens were of very large size. These scarcely got into the water samples, so that the curve taken from the numbers obtained from the water samples gives a wrong impression for this species, although the seasonal distribution is correctly, though roughly, shown.

The Metazoa in the water samples only amount to a few individuals and are of no account, so that the quantitative work practically amounts to an estimation of the unicellular organisms. Whilst counting the diatoms they were estimated, as is usual, by cells ; however, for the tow nettings the chains were regarded as individuals, otherwise the method given above would not have been suitable owing to the number of cells in a chain.

The tables at the end of the paper show the average number of organisms in the water samples in 50 cc. for each week. The tow nettings are shown for comparison at the same time (marked in letters). The account of the Metazoa from the tow nettings is given without tables, and they are also taken into account in the survey for each month. A list of the dates on which the samples were taken, giving wind and weather, will be found at the end of the paper.

The largest numbers, on the whole, are found in the surface layer, but there is not much difference, and a large amount of mixture of water seems to take place, so that it is difficult to assign to any particular species its particular habitat in depth. *Skeletonema costatum* is most frequent at the surface, also *Chætoceras* species generally, *Lauderia*, *Thalassiosira*, and *Mastigloia*. The greatest fluctuations are nearly always from the surface and can usually be traced to the state of the tide, the 5 and 7 fathom layers being much more regular, as was to be expected. *Skeletonema*, as noticed by Gran (1912*b*) is rather more numerous at the surface. *Paralia sulcata*, however, shows all its maximum numbers either at 5 or 7 fathoms, but as this is naturally a bottom form often coming into the plankton, it is not surprising. *Nitzschia delicatissima*, and *Asterionella japonica* also show largest numbers at 5 and 7 fathoms. The state of the tide affects the numbers, more being taken at or just before high tide, fewest at or just before low tide usually. The highest catches usually come with S. and S.W. winds.

The unicellular organisms other than diatoms occur irregularly at all depths.

On comparing the present records with those of Lohmann at Kiel, much that he states is borne out by these results, although many of his numbers are from estimates with filter as well as centrifuge. *Skeletonema costatum*, which he regards as one of the most important diatoms of the plankton, has a curve which is wonderfully in accordance with ours, Fig. 1 having a large spring and a small summer maximum (Lohmann, 1908, table XII).

Of his numerical results the Peridiniales are relatively in much larger numbers than in the present records. Although here many species are found to occur and several new species are described, the individual numbers are usually enormously less in these records, even when the season of maximum number agrees. As Lohmann observed at Kiel, so here, there are several amœbæ to be found in the plankton. Ours are of three kinds, one of which is fairly common. With him *Flagellata* are much more numerous than with us, except *Phæocystis*, which is so abundant here in May and June that it interferes with everything, clogging up all the nets. Infusoria Lohmann finds numerous, and there are numerous species of them here, but they are not found in large numbers with the exception of the *Tintinnoidea*. The smaller forms, such as *Laboea* species

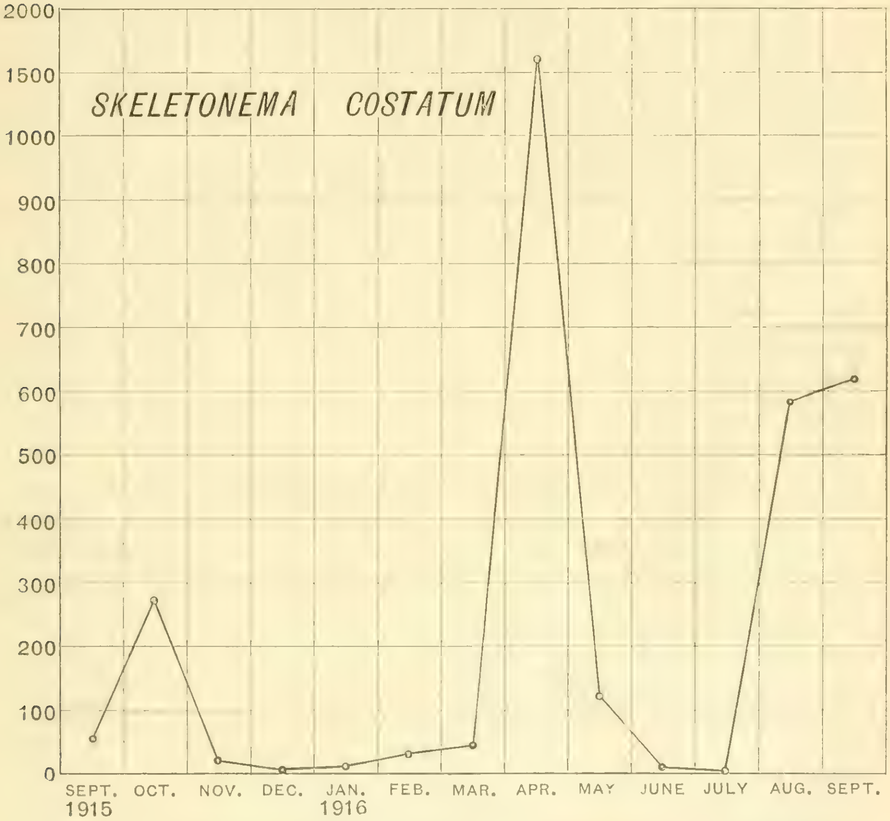


Fig. 1.—Curve of *Skeletonema costatum*, showing average number of individuals in 50 cc. for each month.

and *Strombidium caudatum*, very easily collapse and destroy themselves in a moment. *Tiarina fusus* we find at a larger maximum than at Kiel. Most of the new species, both of the Peridiniales and Infusoria found in the plankton by Lohmann, are present here if not in such large quantities; thus we have *Amphidinium crassum*, *Pouchetia parva*, *Cochlodinium pellucidum*, *Laboea strobila*, and many other species hitherto not known from British seas.

The diatoms, although usually in less numbers than Lohmann's, are in some cases more. Nearly all his diatom numbers are, however, from filter examinations, therefore not exactly comparable. One fact which is striking is the relative regularity of the yearly curve of certain species, instead of their showing a marked seasonal distribution. This we find to be the case with *Thalassiothrix nitzschioides*, which is present at Kiel practically all the year round whilst with us it is a pronouncedly winter form. The same is true with most of the *Coscinodiscus* species which also are winter forms here. This is perhaps to be explained by Gough's theory of the distribution of neritic diatoms which he found occurred at certain definite times only in places near the ocean, but stayed all the year round in suitable localities far removed from it. We find much the same seasons for the above diatoms at Port Erin as we have at Plymouth (see Herdman and Scott, 1908–15).

For comparison I have taken from Lohmann's tables certain species with their maximum number in 100 litres and put side by side of these the Plymouth records of the same species in the same amount calculated from the number in 50 cc. The month of maximum is also recorded. It will be seen that in most cases his numbers are higher, in a few instances much higher, but in three cases the Plymouth numbers are higher.

Species.	*Kiel.*	Month of max.	*Plymouth.*	Month of max.
Paralia sulcata	77,000	Nov.	1,000,000	Nov.
Skeletonema costatum	778,000,000	June	25,000,000	April
Guinardia flaccida	360,000	May	20,000	Sept.
Asterionella	1,800,000	Dec.	3,260,000	July (*japonica*)
Prorocentrum micans	5,100,000	Aug.	128,000	Sept.
Glenodinium bipes	2,100,000	May	12,000	Aug.
Ceratium fusus	300,000	Sept.	12,000	Aug.
			P. armata	
Pouchetia parva	50,000	Sept.	30,000	June
Tiarina fusus	11,000	Oct.	14,000	Aug.

As will be seen, the maxima here agree in most cases in being in the spring or autumn. As has been stated above, however, there are several species which do not agree; for instance, *Coscinodiscus Granii* has a maximum at Kiel in August, whereas I found it confined to the period from November to April, when it is fairly evenly distributed. The maximum of *Prorocentrum micans* in August or September seems to be well established. Ostenfeld (1913) is here also in agreement. *Ceratium fusus* also has its maximum at this time, and *Pyrocystis lunula*, which at Plymouth is only recorded in these months. However, I find that in many cases species having a spring maximum at Kiel have it here in the summer.

A comparison of the present results, with those of Gran (1912) is difficult as his are only for the month of May and from so many stations at various localities and many different depths. However, if we take the Dutch results from the south-western part of the North Sea, which is the nearest to us of all the localities he makes use of, and compare them with the present records for the month of May only, we find the comparison is not without interest. Gran used the centrifuge entirely and the samples were all preserved. He usually took 50 cc. of the sample and calculated from it the number of individuals in a litre. Except in certain cases mentioned below, the numbers are not extremely different. Thus we find the species of *Biddulphia* present in very small numbers (only *B. sinensis* at Plymouth), a large number of several *Chætoceras* species in both (12 species with him, 8 with us). However, whereas there *C. decipiens* and *debile* are the prevailing forms (maximum numbers 11,500 and 6,500 per litre respectively) the prevailing forms here are *C. curvisetum* (maximum number 39,900 per litre) and *C. pseudocrinitum* (maximum number 30,000 per litre). A large number of resting spores of *Chætoceras* species are recorded by Gran and also by Lohmann. They were not recognised and therefore not recorded in the present paper. *Lauderia borealis* (Gran's maximum 2,180 per litre) with us is more abundant (21,580 per litre). *Paralia sulcata* (Gran's maximum 7,180 per litre at 30 m.), with us 700 per litre at 7 fathoms. *Rhizosolenia* species fairly abundant:

	Dutch records.	Plymouth records.
R. alata . . .	300 (15 m.)	120 surface
R. semispina . .	160 (20 m.)	500 5 f.
R. Shrubsolei . .	480 (10 m.)	1,600 5 f.
R. Stolterfothii . . .	8,360 (50 m.)	760 surface

Thalassiosira gravida (Gran's maximum 1,760 per litre, Plymouth 6,320 per litre). *Nitzschia delicatissima* much more abundant at Plymouth, *Nitzschia closterium* more abundant in the Dutch records. Of the Silicoflagellata *Dictyocha fibula* and *Distephanus speculum* are few in numbers as in our records, also the individual numbers of the Peridiniales which are often represented by single examples or by twos and threes. It is, however, among the Infusoria that a great difference is seen, for whereas my own records seldom show more than a few specimens in each sample, the small Infusoria are in fairly large numbers in the Dutch records, especially the species of *Laboea*, which sometimes reach five figures per litre. The Metazoa agree with my records in only being represented by very few individuals.

Herdman's (1908–15) quantitative estimates of the plankton for Port Erin and the south end of the Isle of Man are taken from the tow nets only. These are only comparable with the present records to a certain degree, but some facts stand out as of special interest. Here we find the large spring and smaller autumn maximum for the diatoms, the seasonal distribution of certain genera and their maxima, *Rhizosolenia* species in June; *Chætoceras*, *Thalassiosira* and *Lauderia* in April and May; *Chætoceras* and *Lauderia* again in September and October; all these agree well with our records. The species of *Biddulphia* agree in being almost entirely absent from June to August and being much the most common from November to May. *Coscinodiscus* again agrees in being absent in the summer and early autumn and common in winter and early spring, *Rhizosolenia* species being only common in summer. *Thalassiosira* has its maximum in May both at Port Erin and Plymouth, with a slight second maximum at Plymouth in 1916. *Guinardia* is slightly earlier at Port Erin than at Plymouth. *Lauderia* with a large spring and small autumn maximum at both places, and the same with *Chætoceras*. *Asterionella japonica* appeared in large quantities in May, 1913, at Port Erin. At Plymouth it has a maximum in July and is present on and off from April to January, common through July and August. Apparently this species is irregular in its appearances, as Gough records it from Plymouth as cc in May. The numbers of Peridiniales at Port Erin are enormous compared with the present results; *Ceratium* species and the larger *Peridinium* species forming the basis of the Port Erin records. However, we are in agreement in finding the Peridiniales maximum to occur very shortly after the diatom maximum and the maximum a single one which is only in the summer, May usually at Port Erin, June this year for Plymouth, when the curve shows a conspicuous hump, gradually dwindling in September, after which month very few are present. The smaller Peridiniales are not taken into account in the Port Erin reports, and the *Gymnodiniaceæ*, which turn out to be abundant, are necessarily not noticed as they come through the nets. The same applies to the other small unicellular organisms.

The Diatoms.

In estimating the diatoms, we find they fall naturally into two groups: the first and most important includes the species beginning about April and usually ending about September, the second including those having their maximum in the winter or spring and extending from September or October to the end of March or April and May. In September these groups sometimes overlap, but the two large general maxima occur about April and from August to October, the diatoms of the first group thus being mainly responsible for both the spring and autumn maxima.

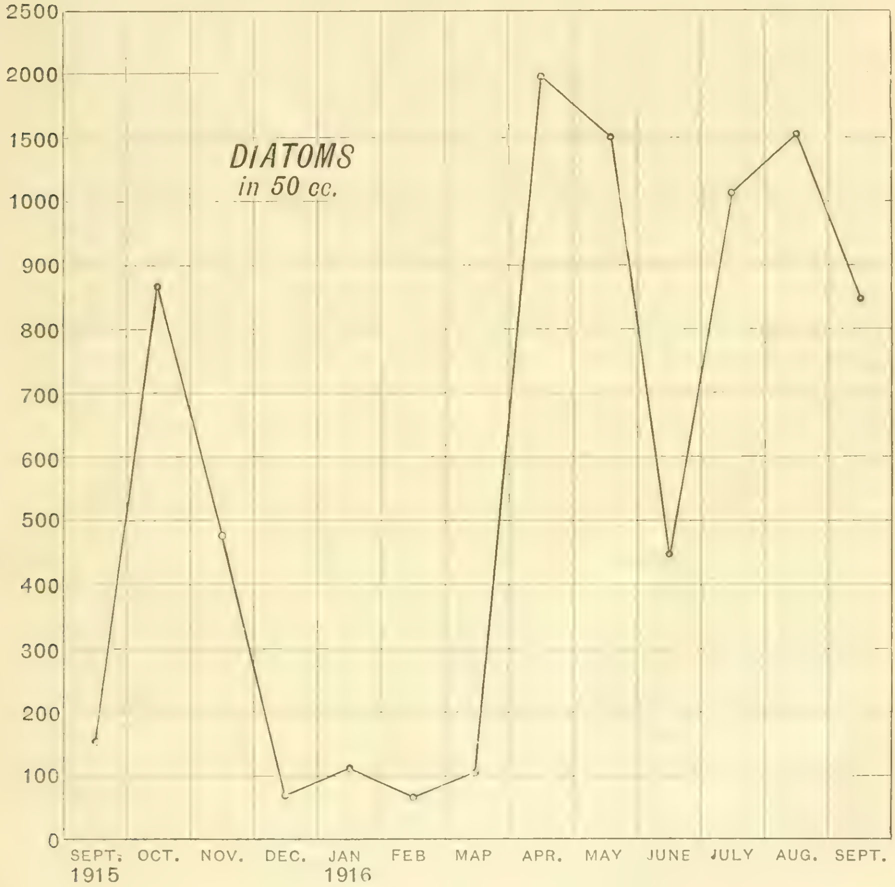


Fig. 2.—Curve showing average number of diatoms in 50 cc. for each month.

The curve here given (Fig. 2) shows the average number of diatoms in 50 cc. monthly throughout the year. The largest maximum is in April, although May comes very near. The autumn maximum here this year is early and occurs in August. It is very nearly as big as the spring maximum. Also in the curve there is another maximum in October, 1915, after which the numbers are very low, until they suddenly rise enormously in April. The October maximum is possibly the ordinary autumn maximum occurring later in 1915 than in 1916. For the rise in April *Skeletonema costatum* is almost wholly responsible ; in May *Chætoceras* species are mainly responsible, together with *Nitzschia delicatissima*, *Thalassiosira gravida* and helped by *Rhizosolenia* species and *Lauderia borealis*. For the August maximum *Chætoceras* again is to the fore with *Asterionella japonica*, *Mastigloia* at times in numbers, *Rhizosolenia* species and *Nitzschia* species. The rise in October, 1915, is due to *Mastigloia*, *Chætoceras*, *Lithodesmium undulatum* and *Skeletonema costatum*.

The diatoms of the first or spring and summer group include the genera *Asterionella*, *Chætoceras*, *Lauderia*, *Nitzschia*, *Rhizosolenia* and *Thalassiosira* ; those of the autumn and winter group include *Biddulphia*, *Coscinodiscus*, *Paralia*, *Streptotheca* and *Thalassiothrix*. One of the most important diatoms is *Skeletonema costatum*, which, although occurring practically all the year round, yet has certain times of total disappearance for short periods. It cannot be placed in either of the above-mentioned groups as it extends over both.

We find this year the genera *Biddulphia* and *Coscinodiscus* disappear suddenly and do not continue in small numbers through the summer, as is the case generally at Port Erin. Gough, however, has recorded *Biddulphia mobiliensis* in June and August from Plymouth, so it must occasionally be present ; also *Coscinodiscus* species very rarely. *Paralia* and *Thalassiothrix* are essentially winter forms here, the latter stopping abruptly in the spring and the former being much commoner in the winter, although occurring throughout the year. The records of Bygrave and Gough are here also in agreement.

Several important species have only one maximum in the year. Monthly curves show a gradual decrease from it. *Asterionella japonica* (July), *Rhizosolenia Stolterfothii* (May), *R. alata* (June), *R. Shrubsolei* (May), *R. hebetata* f. *semispina* (May), *R. setigera* (August), are examples ; also *Biddulphia* species and *Coscinodiscus* species (autumn to spring) the curves of which could not be exactly determined because of their presence only sparingly in the water samples. The following are some of the most important species which have two maxima : the larger in April, May or June, usually very much exceeding the second in August or September : *Skeletonema costatum* (April and September), *Chætoceras curvisetum* (May and September), *Lauderia borealis* (April and August), *Thalassiosira gravida* (May and September). These results agree roughly very well with the previous records for Plymouth by Gough and Bygrave.

Large masses of a species of *Mastigloia* in a gelatinous sheath sometimes occur at intervals and swell the number of diatoms largely. In these cases they are usually so numerous that I have estimated them in 10 cc. instead of 50 ; I have also done this with other species when very numerous.

Table II shows the average number of diatoms in 1 cc. for each month. In the following details of the species the classification of " Nordisches Plankton," Vol. III, Gran (1905) is used.

(1) *Melosira Borreri* Grev. Not common. In water samples, October to March.

(2) *Paralia sulcata* (Ehr.). Occurs almost all the year round in small numbers, but is essentially a winter species. Common from October to April with a maximum in November, then dwindles and picks up again in August. Nearly always goes through the nets. More frequent at 5 and 7 fathoms although common sometimes at the surface. Belongs, properly speaking, to the bottom but very often comes up to be a true member of the plankton.

(3) *Skeletonema costatum* (Grev.). Very common for nearly the whole year, but has periods of disappearance. Rare in December and part of January, June and July. Maximum of 250 per cc. in April, when it helps largely in making the spring diatom maximum. Very numerous in August, September and October. A smaller second maximum in August, and in October, 1915, a still smaller one. Lohmann considers *Skeletonema costatum* the most important diatom at Kiel, where in June it reached a maximum of 780,000,000 per 100 litres. He finds it prefers water of 10 m. depth. Gran (1912*b*) shows it likes surface water, and I have found that although common in all three depths it is usually commonest in the surface samples and its maximum of 12,500 in 50 cc. is from the surface. This is one of the most important of the plankton diatoms at Plymouth, but passes through the net in quantity.

(4) *Thalassiosira gravida* Cleve. This is the only species of the genus found commonly in the water samples. It is abundant from the end of March to the middle of September with an interval of scarcity in July and August. May and June are the months given by Herdman for the maximum of the genus at Port Erin, which agrees well with us. It occurs at all depths, but its maximum in May of 316 in 50 cc. is from the surface.

(5) *T. Nordenskioldii* Cleve. Not very common, occurring at intervals. Frequent in May.

(6) *T. decipiens* (Grun.). Rare.

(7) *T. subtilis* (Ostenf.). This little species with its surrounding matrix occurred only rarely in 1916, although it was frequently noticed in 1915.

(8) *T. condensata* (Cleve). Very rare.

(9) *Lauderia borealis* Gran. An important part of the plankton from May to September, with intervals of scarcity. Helps largely in forming both diatom maxima. Rare from late autumn to early spring. Maximum in May. Its seasonal distribution agrees with Herdman's records for Port Erin. At all depths, but largest numbers at the surface. Maximum of 1,079 in 50 cc. in May from the surface.

(10) *Leptocylindrus danicus* Cleve. Fairly common from May throughout the summer, at other times very rare.

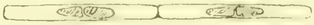


FIG. 3.—*Leptocylindrus sp.* × 700.

(11) *L. sp.* (Fig. 3). A small species which is like *L. minimus* Gran (1912), but never twisted as he describes; occurs fairly commonly in the summer plankton. There are seldom more than two cells in a chain and these are always quite straight. The two chromatophores, size and form agree with Gran's species.

(12) *Guinardia flaccida* (Castr.). Common at intervals from April to September, with a maximum in July. More common in the very fine tow nettings than in the water samples. The large numbers occurring at Port Erin in May and June (maximum in June) are noticeable.

(13) *Hyalodiscus stelliger* Bail. Fairly common from October to February; a winter species. At other times rare.

Genus COSCINODISCUS Ehr.

All the species of *Coscinodiscus* we have found practically absent during the summer, which agrees well with Port Erin; although they continue through the year there except sometimes for one month, they are in very much smaller numbers through the summer. From September to May they occur at times abundantly and are common in the very fine tow nettings.

(14) *Coscinodiscus excentricus* Ehr. Common from September to May.

(15) *C. radiatus* Ehr. Common from September to May. *C. excentricus* and *C. radiatus* are the most abundant species.

(16) *C. sub-bulliens* Jörg. Only noticed from September to December. Not very common.

(17) *C. Granii* Gough. Begins in November and remains till April. Sometimes common in December, January and February.

(18) *Actinocyclus Ehrenbergi* Ralfs. In tow nettings only. Rare. September.

(19) *Actinoptychus undulatus* (Bail.). From the middle of September to the end of April, never very abundant, more frequent in tow nettings than in the water samples. Not seen at all in the summer.

Genus RHIZOSOLENIA (Ehr.) Brightw.

With the exception of *R. robusta* which is the only winter form all the species of *Rhizosolenia* are markedly summer forms; beginning to be abundant in May they continue common until the end of September at all depths. If we compare this with the Port Erin records we find it agrees well except for the fact that at Port Erin there are very few present in August.

The curve (Fig. 4), giving the distribution of the various species, shows *R. Stolterfothii* as much the most abundant with a big maximum in June. As mentioned above, however, *R. Shrubsolei* occurred in enormous numbers in June in the tow nets, of a large size, and was not adequately represented in the water samples. The maximum of the species on the curve ought to rise very much higher. I find that *R. Shrubsolei* and *Stolterfothii* run together to a great extent, although *Shrubsolei* almost disappears in July, whilst *Stolterfothii* continues common well into September. The genus is hardly represented at all from November to April. Its absence being very striking, *R. alata* follows *R. Stolterfothii* closely, although it is not so common. *R. hebetata* form *semispina*, has its maximum in May. *R. setigera* is later, beginning in June and ending in September, with a maximum in August; thus it is later and remains less time than any of the others. All the species are abundant in the tow nets.

(20) *Rhizosolenia Stolterfothii* H. Perag. Perhaps the commonest of the *Rhizosolenia* species. Very common from May to September, with a maximum in June; disappears entirely in December.

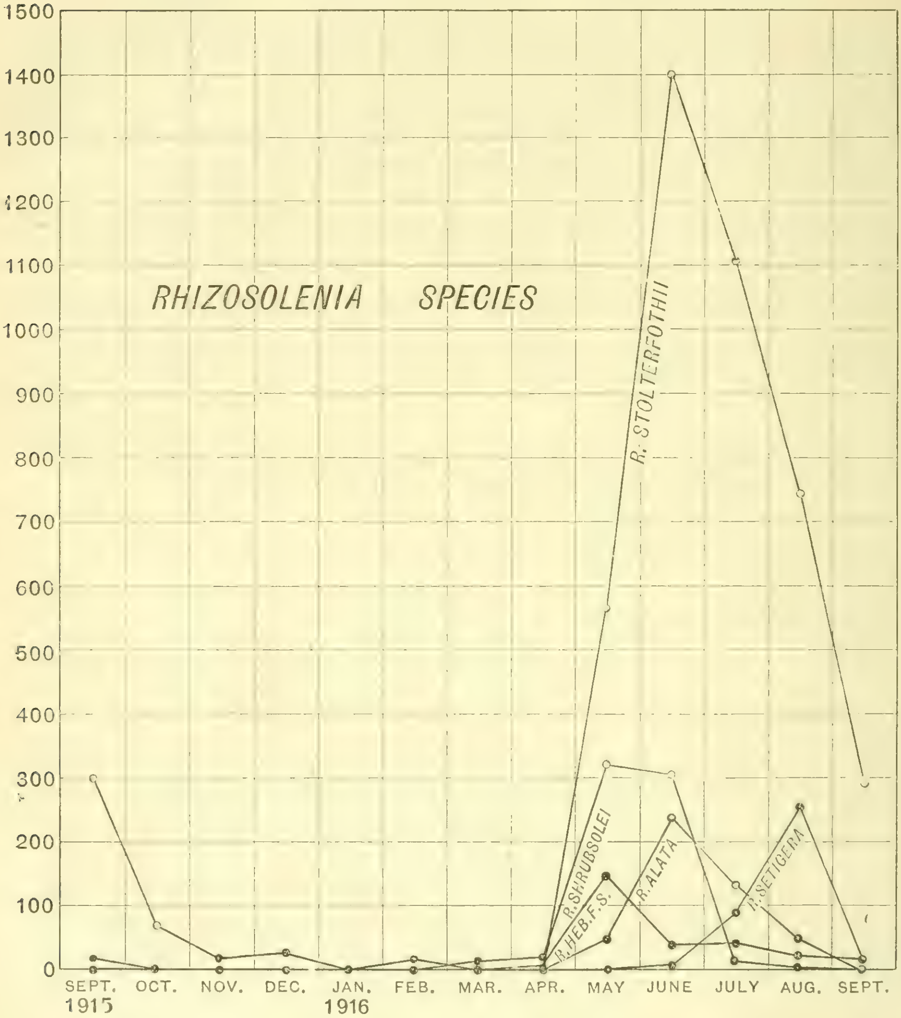


FIG. 4.—Curve showing average number of *Rhizosolenia Shrubsolei*, *Stolterfothii*, *alata*, *setigera*, and *hebetata f. semispina* in 1000 cc. for each month.

In the tow nettings it occurs in long spirals with many cells in each. In the water samples, however, these are broken up and only a few cells cling together, and many single cells are present.

(21) *R. robusta* Norman. This is the only winter *Rhizosolenia* here. It begins in November and, although never common, continues till April. Chiefly in the tow nettings. Very seldom in the water samples.

(22) *R. Shrubsolei* Cleve. Very common in May till the end of June, then dwindles and is rare in August, almost absent in the winter.

(23) *R. setigera* Brightw. Very common in July and August, when it seems to take the place of *R. Shrubsolei*; rare in spring and autumn and almost absent in winter.

(24) *R. hebetata* (Bail.) f. *semispina* (Hensen). Begins in May and is very common till the middle of August, after that is rare and disappears entirely in the winter.

(25) *R. alata* Brightw. Begins to be common in June and continues till August, after that is only rarely found, although a few stragglers are present throughout the year.

(26) *Corethron criophilum* Castr. Most frequent in October but never common. Absent for nearly the whole summer.

Genus CHÆTOCERAS Ehr.

Although scattered throughout the year, all the species occur chiefly in the spring, summer and early autumn, forming an important portion of both maxima. A very large maximum in May (Fig. 5) agrees with the Port Erin records, but the autumn maximum in August is small, not amounting to more numbers than in March. This rise in March is partly due to numbers of *C. densum*, the maximum number of that species in the water samples. This species, however, is large and, like *C. boreale*, does not get much into the water samples. *Chætoceras curvisetum*, which is much the commonest species found, shows two well-marked maxima, a large spring and a small autumn maximum, these agreeing with the Port Erin records for the genus. The fact that on several days in early autumn no *Chætoceras* species were seen in the water samples brings the average for the month down.

(27) *Chætoceras densum* Cleve. Frequent in the tow nettings, but too large to be found much in the water samples. Present most of the year except at times in the summer.

(28) *C. convolutum* Castr. From spring to autumn, sometimes abundant

(29) *C. danicum* Cleve. Rare, at intervals through the year

(30) *C. boreale* Bail. Chiefly in two nettings. Occasionally in spring and early autumn.

(31) *C. decipiens* Cleve. Fairly common in spring and summer, rare in autumn and winter.

(32) *C. teres* Cleve. Chiefly in February and March, common in March.

(33) *C. contortum* Schütt. Occasionally in July, August and September.

(34) *C. didymum* Ehr. Begins in February and continues through the spring and summer until October. Very common in August.

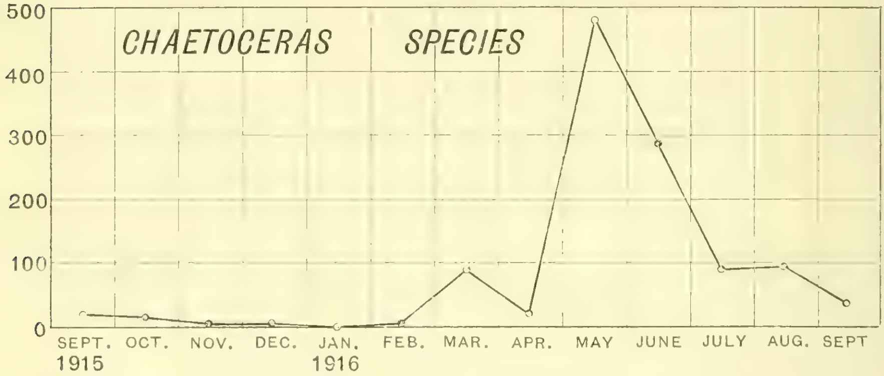


FIG. 5.—Curve showing the average number of *Chætoceras* in 50 cc. for each month.

(35) *C. constrictum* Gran. One of the commonest species from July to the end of September with its maximum in May when it suddenly appeared and disappeared. Resting spores noticed commonly in August forming in the chains. At all depths, but the largest numbers nearly always at the surface.

(36) *C. Willei* Gran. Rare from June to October.

(37) *C. breve* Schütt. Rare in August. This is recorded often by Gough.

(38) *C. laciniosum* Schütt. Occasionally from June to October.

(39) *C. diadema* (Ehr.). Only seen once in August.

(40) *C. pseudocrinitum* Ostenf. Common in May and June, at other times rare. At all depths.

(41) *C. curvisetum* Cleve. The commonest species of *Chætoceras*: beginning in March it continues throughout the summer till the middle of September. Maximum of 37 per cc. at the end of May. This is certainly the most important species of *Chætoceras* here and helps greatly to swell the diatom maximum both in May and August. Largest number at the surface, although it occurs at all depths.

(42) *C. debile* Cleve. Not very common, May and June.

(43) *Chætoceras* spp. Species which could not be identified were common in July and August.

(44) *Eucampia zoodiacus* Ehr. Occasionally from May to October.

(45) *Streptotheca thamensis* Shrubs. Common from September to April, otherwise rarely seen. More frequent in tow nettings than in water samples.

(46) *Cerataulina Bergoni* H. Perag. Fairly common in May and June.

Genus BIDDULPHIA Gray.

The *Biddulphia* species are practically confined to the autumn, winter and early spring, being almost entirely absent in the summer. This agrees fairly well with the Port Erin records, although there, in small numbers only, they are found in the summer. At any rate they may be regarded as winter, or early spring, and autumn forms. *B. mobiliensis*, *regia* and *sinensis* are all common in the early spring, winter and autumn. Whether *B. regia* and *sinensis* should be regarded as good species is a matter discussed at length by Herdman (1912), who has shown that intermediate forms are to be found and has figured forms from Port Erin which appear to be half *B. sinensis* and half *B. regia* or *mobiliensis*, his final decision being that they are probably all the same species. He therefore regards *B. sinensis* and *B. regia* as distinct forms of *B. mobiliensis*. There seems to be no doubt about the sudden appearance of the exotic species *B. sinensis* in numbers at Port Erin in November, 1909, and also that it suddenly appeared at the mouth of the Elbe in 1903, as is shown by Ostenfeld (1908): having spread from the mouth of the Elbe into various places including the North-East of Scotland it was then found on the Belgian coast, Ostenfeld accounting for its presence there by imagining a reversal of the usual north-going current. Its first appearance at the mouth of the Elbe Ostenfeld thinks is probably due to its being taken there by some ship. In 1908 he predicted its discovery in the Channel, as up to that time it had not been found to occur there. In order to ascertain whether it was present in Plymouth in former years (it certainly is common here now) I examined a large number of old tow nettings mostly from the West Channel, Plymouth, and all from this district. Beginning in 1897 I searched through samples of various dates, particularly autumn, winter and spring, without finding any trace of *B. sinensis* until October, 1909, when it suddenly became abundant and continued so within the limits of its seasonal range as is shown in these records until the present time. It is very distinct and easily recognised and I find it hard to believe it is not a true species distinct from *mobiliensis* and *regia.* It occurs with them and is easily distinguished from them, and this year continues to stay longer than the others. The fact also, quoted by Herdman, that Dr. Allen and Mr. Nelson grew cultures of all three forms, which bred true for a year is strong evidence in favour of their being separate species. In some samples taken by Dr. Garstang in 1897 *P. mobiliensis* and *regia* were common, and amongst these I found an occasional specimen which showed an approach *to sinensis.*

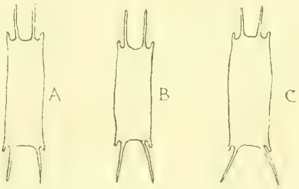


FIG. 6.—Varieties of *Biddulphia regia.* × 60.

The figures (Fig. 6) were drawn with the camera lucida, and are very like some of Herdman's figures. Although, however, one end is decidedly like *sinensis* and the cell is elongated (probably soon going to divide), I think these are varieties of *regia* only and not true *sinensis* species. It seems from this that occasionally *B. regia* can show varieties approaching *B. sinensis* and perhaps this is the explanation of Herdman's mixed forms. If this explanation be correct we thus find *B. sinensis* appearing at Plymouth suddenly in October, 1909, and at Port Erin in November of the same year. The difficulty as to its origin is still a puzzle.

(47) *Biddulphia mobiliensis* (Bail.) Grun. Begins to be abundant in the middle of November, keeping up its numbers until the end of March, is scarce in April, finally disappearing at the end of the month, not to reappear until the middle of August and then only singly.

(48) *B. regia* M. Schulze. Much the same as *B. mobiliensis* but not quite so abundant and disappears earlier.

(49) *B. sinensis* Grev. Not so abundant as the other two but fairly common, continues until the end of May.

(50) *B. favus* (Ehr.) v. Heurck. Rare, February and April.

(51) *B. alternans* (Bail.) v. Heurck. Rare, October and early spring.

(52) *Bellerochia malleus* (Brightw.) v. Heurck. Rare, September.

(53) *Lithodesmium undulatum* Ehr. Common from August to October, rare at other times.

(54) *Ditylium Brightwelli* (West) Grun. Appears and disappears periodically from January to September. In March and September very common in the tow nets.

(55) *Fragillaria* sp. Sometimes present in long strings in summer.

(56) *Thalassiothrix nitzschioides* Grun. Common from September to the end of April. A winter species In summer rare or entirely absent.

(57) *Asterionella japonica* Cleve. Important in the late summer. Occurs in single groups rarely at intervals from October to the end of June, then suddenly becomes very common in July, rising to over 478 per cc. at the end of the month, abundant in August and gradually dwindles through September. Present in the tow nettings as well as the water samples. This seems to be erratic in its appearance as Gough records it as cc. in April and May (as *A. glacialis*). The largest numbers occur at 5 and 7 fathoms, maximum at 5 fathoms.

(58) *A. Bleakeleyi* W. Smith. Only occurred twice, November and December.

(59) *Lycmophora Lynbergi* (Kütz) Grun. Rare, at intervals through the year.

(60) *Grammatophora serpentina* Ehr. A littoral species, rare.

(61) *Acnanthes longipes* Ag. Rare, in tow nettings, autumn and early spring.

(62) *Navicula membranacea* Cleve. Fairly common from July to November.

(63) *N.* sp. Many species of *Navicula* occurred through the year which were not identified.

(64) *Pleurosigma* sp. Several species occurred through the year.

(65) *Mastigloia* sp. Occurred at intervals in such numbers as to materially influence the records. The large numbers are always at the surface, although in July and August it occurs at all depths.

(66) *Amphiprora maxima* Greg. Rare, chiefly in autumn and winter.

(67) *Amphora ostracaria* Breb. Rare, only in autumn.

(68) *A.* sp. Rare, September and August.

Genus NITZSCHIA Hassal.

The species of *Nitzschia* occur throughout the year and, unless entangled in larger organisms, get through the nets in numbers. In *Phæocystis*, *Nitzschia* species entangle themselves to a large extent, chiefly *N. closterium* and a needle-like species which I believe to be *N. delicatissima*. However, when it is entangled it is generally single or there are two together. It is never in a chain or three or five as is often the case with this species when it is free. When not entangled it is not so common.

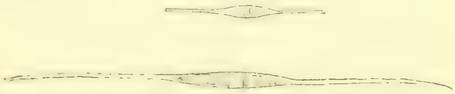


FIG. 7.—*Nitzschia closterium* W. Sm. Long and short forms. × 350.

(69) *Nitzschia closterium* W. Sm. Occurs throughout the year. Never in very large numbers. Two forms are seen (Fig. 7), the long form with its ends curled slightly and a much smaller form with straight ends. Possibly the latter is the young just after division. In cultures the central part is very often much inflated. At all depths.

(70) *N. seriata* Cleve. Fairly abundant in August and September, rare at other times.

(71) *N. delicatissima* Cleve. In May and June this species plays an important part in the plankton. From July to the middle of September it is fairly common, after that occurring only occasionally. At all depths but largest numbers at 5 and 7 fathoms.

(72) *N. panduriformis* Grev. Very rare, September and October.

(73) *Bacillaria paradoxa* Gmel. Never in large numbers, but occurs throughout the year both in water samples and tow nettings. Almost absent in May and early June.

(74) *Campylodiscus* sp. At least four species of *Campylodiscus* occur in the tow nettings occasionally. Also *Surrirella fastuosa* Ehr. is fairly common. All these are bottom forms and do not strictly belong to the plankton.

THE PERIDINIALES.

In the microplankton the group of Peridiniales comes next to the diatoms in importance. A very large number of these go through the finest net, and practically all the smaller forms including almost the whole of the *Gymnodiniaceæ* are lost. Former tow-net records show hardly any of these. *Ceratium* and the larger *Peridinium* species have been shown to be plentiful, but there is a very marked absence of the smaller forms. This is perhaps the group which shows the loss from the net to the greatest degree. Because of the number of new species and new records of this group I have given the systematic details in a separate paper of this journal (p. 183). Lohmann has described many new forms from the microplankton, and several of these are found to occur here. In most cases his numbers are much greater than mine; also the numbers given in Prof. Herdman's records for Port Erin are very large, but the different methods employed make the two records hardly com-

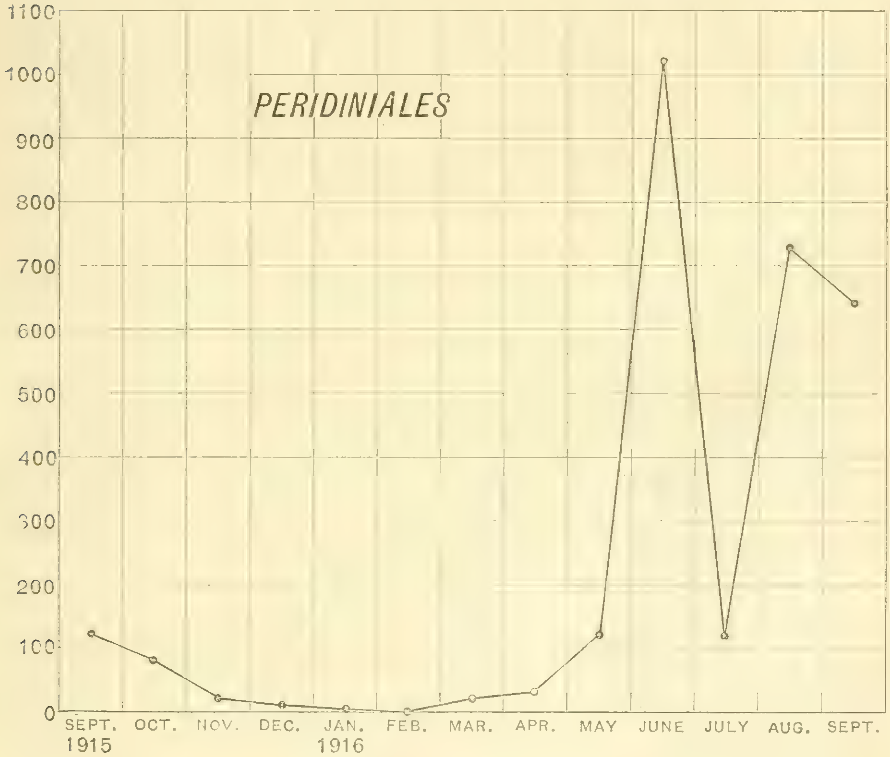


FIG. 8.—Curve showing the average number of Peridiniales in 1000 cc. for each month.

parable. Probably many of the more delicate forms are lost, but the relative seasonal abundance is well shown by the curve (Fig. 8) which shows June as the maximum month, thus agreeing with other observers. In this curve there is a depression in July which may be due to the fact that most of the samples were preserved in that month, rather than to the fact that the numbers are much less than in August. From September the curve falls and is very low until May, showing an almost complete absence of Peridiniales in the winter. Even if some of the individuals are lost the results show well the relative abundance of the species. *Prorocentrum micans* which is largely lost in the tow nettings is one of the few which has an autumn maximum, thus agreeing with the observations of other workers (Lohmann, 1908; Ostenfeld, 1913). Table 2 shows the average number of Peridiniales per cc. for each month. These numbers possibly do not show the real abundance of such large forms as *Ceratium* and the larger *Peridinium* species, which are often very common in the tow nettings when there are few in the water samples.

The 5-fathom samples are found to be richer in specimens than the 7-fathom samples. Usually they are more abundant at the surface than at 5 fathoms, but the species all occur in all the depths. It is well known that the Peridiniales form a large portion of the food of many of the plankton animals. *Actinotrocha* which sometimes occurs in the tow nets is a good instance of this, and the species which have just been swallowed can nearly always be identified. The following list shows the contents of five specimens taken June 25th, 1915:—

Specimen.	1	2	3	4	5
Peridinium ovatum . .	1	1	1	2	1
,, pallidum . .	3	—	—	—	-
,, pellucidum . .	—	1	2	9	2
,, sp. . . .	5	—			
,, sp. Juv. . .	3	—	—	—	
Pouchetia armata . .	—	2	—	1	2
Dinophysis acuminata . :	—	2			
Other organisms . . .	—	1	—	5	

FLAGELLATA.

"Nordisches Plankton," Vol. 2.

Phæocystis is certainly by far the most important of the flagellates, which interferes enormously with the catches by blocking up the tow nets in the early summer and entangles in its gelatinous covering many diatoms and Peridiniales. It also serves as food for many of the plankton organisms. I have recorded this species by colonies instead of cells, as it was practically impossible to count the latter.

Halosphæra viridis comes next in importance, its swarm spores occurring oftener in the water samples than the spheres themselves. The other flagellates occur sparingly but belong to the genera recorded by others from plankton and are almost entirely missed by the nets.

Oxyrrhis marina I have placed with the Peridiniales; this species and a small species of *Carteria*, although not often found in the water samples, multiply freely in cultures where they are often found. The numbers obtained for flagellates, with the exception of *Phæocystis*, are much smaller than Lohmann's.

(1) *Phæocystis Pouchetii* (Hariot) Lagerheim. Begins to be common in the middle of May and continues till the middle of June, interfering with all the tow nettings. Rare at other times. Not many colonies get into the water samples. The unidentified flagellates are chiefly swarm spores, probably of *Phæocystis*.

(2) *Dinobryon* sp. (cf. *balticum* (Schütt) Lemm.). Rare in August in the water samples in small colonies. A minute species.

(3) *Carteria* sp. A very small species, rare, in water samples only.

(4) *Trochiscia Clevei* Lemm. Rare, September and May.

(5) *Halosphæra viridis* Schmitz. Not uncommon from September to February. Very frequent in summer, especially the swarm spores, usually swimming freely but sometimes still in the parent sphere.

COCOSPHAERALES.

"Nordisches Plankton," Vol. 2.

Pontosphæra Huxleyi Lohmann. This is the only species found. It occurs occasionally in summer and in early autumn is sometimes abundant.

Coccoliths of other species are very rarely seen.

SILICOFLAGELLATA.

"Nordisches Plankton," Vol. 2.

The usual two species occur fairly commonly in the water samples.

(1) *Dictyocha fibula* Ehr. From September to December and from March to September. Commonest in September.

(2) *Distephanus speculum* (Ehr.) Haeckel. Throughout the year, except in mid-winter, rather more abundant than *Dictyocha*. Commonest in September and October.

RHIZOPODA.

Amœbæ, as Lohmann has pointed out, are not uncommon in the plankton. He records two forms, the largest number being 75,000 in 100 litres, but usually much less. He found July and August were the months in which they occur, and they were only found in depths of 5 and 10 m. I find them from May to October, the greatest number being 140 in a litre. However, I have seen them much commoner than this in surface samples in 1915 when they were not counted. They occur in the surface water and also from 5 and 7 fathoms, the greatest number being from the surface. They are to be found either by examining the water directly or keeping it for a day or two, and, I think, there is no doubt that they are really free-living and do not come from harbouring in other animals. Three forms occur, one very much more common than the others. I have designated them A, B and C. B is very common, A and C only occurred once each. A prominent feature of all is the form of the pseudopodia, which are all spiky when fully outstretched and in the forms A and B give the animal the appearance of a heliozoon. However, they were constantly observed to retract and were in reality perfectly soft although apparently firm.

Form A (Fig. 9, A, 1, 2 and 3), a very minute species, pale greenish brown with very long and exceedingly slender spine-like pseudopodia. Greenish and brown granules inside. Circular even when the pseudopodia are retracted.

Form B (Fig. 9, B, 1, 2 and 3). Very common, larger than A, hyaline and perfectly colourless. Perhaps this is the same species as Lohmann's No. 2. The pseudopodia stick out in regular spikes, much shorter and thicker than in A. These move in various ways and can be completely retracted. May to October. Maximum in May.

Form C (Fig. 9, C, 1, 2 and 3). A very clear and also perfectly colourless form with a conspicuous central nucleus. At one end only is a small frill of spiky pseudopodia. These are usually in the same position, but are capable of being changed and appearing in another place.

All these Amœbæ are entirely lost by the nets.

Heliozoa indet. Rare, only in November.

Foraminifera indet., including *Polystomella* sp., occurred fairly frequently in the tow nets, especially in winter when they were stirred up from the bottom.

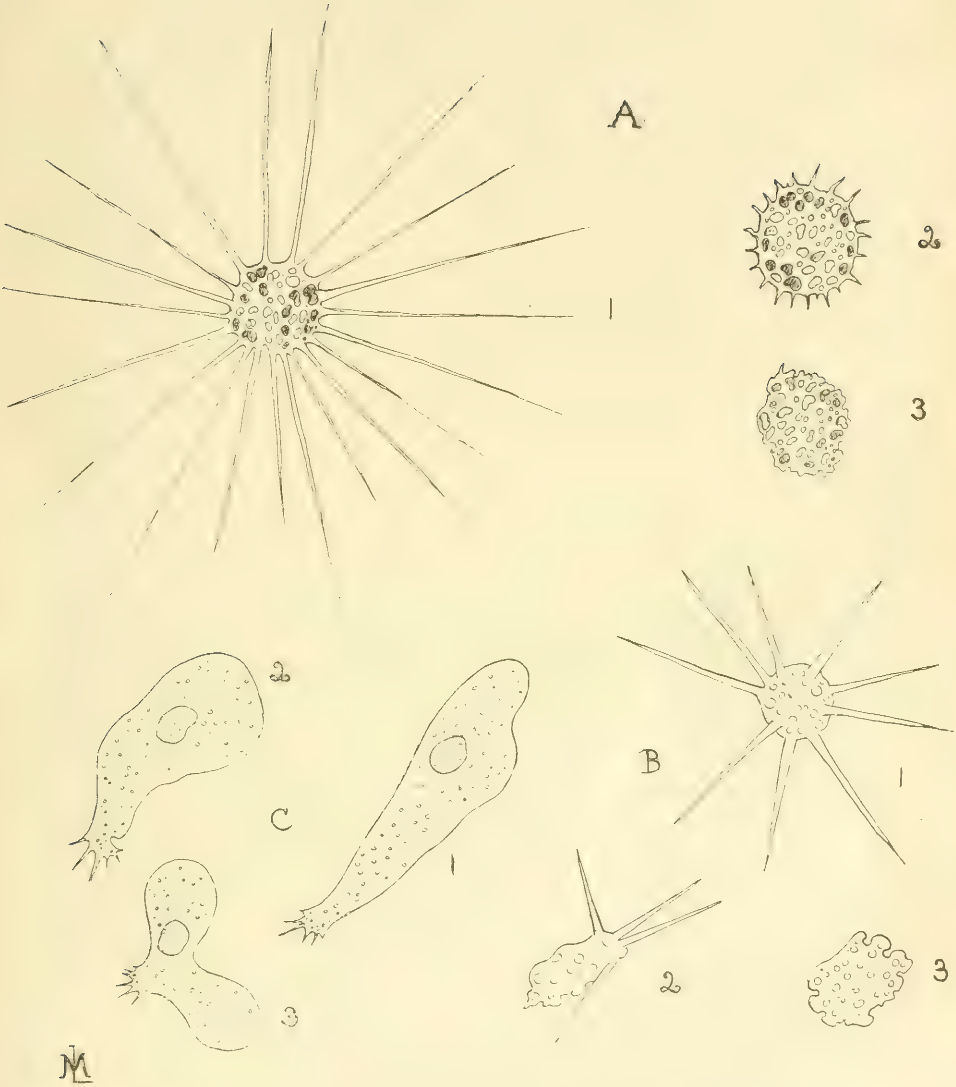

A
1
2
3
B
1
2
3
C
1
2
3
ML

Fig. 9.—Amœbæ from the plankton. A × 500, B and C × 350.

RADIOLARIA.

"Nordisches Plankton," Vols. 3 and 17.

(1) *Acanthochiasma fusiforme* Haeckel. At intervals throughout the year, sometimes abundant in June and October.

(2) *Lithomelissa setosa* Jörg. Rare, November and December.

(3) *Amphimelissa setosa* Cleve. Rare, October to May.

SUCTORIA.

"Nordisches Plankton," Vol. 16.

(1) *Paracineta limbata* Maup. Rare, November to January.

(2) *Acenita tuberosa* Ehr. v. *Fraiponti* (Fr.). Only once in October.

(3) *Ephelota crustaceorum* Haller. Once in November on the legs of a Copepod.

INFUSORIA.

"Nordisches Plankton," Vol. 15.

The Tintinnoidea are much the most abundant of the Infusoria, as Lohmann found. However, a large number of small Infusoria are lost completely by the nets, and these are fairly common in the water samples. Many of them are exceedingly fragile and very easily destroyed. Probably many of them are lost. Among those commonly found is a small species of *Mesodinium* allied to *M. pulex*, which is very difficult to count as it jumps about and collapses before it can be preserved. Species of *Laboea* are also common. Others unidentified are many and varied.

Tintinnopsis ventricosa which is common in the water samples as well as the tow nettings has a maximum of 300 in a litre in June Lohmann found its maximum was 8800 in 100 litres. However, *T. beroidea* at Kiel had a maximum of 1,200,000 per 100 litres, while here its maximum number was 460 in a litre.

Several of the species originally described by Lohmann are found to occur here and some of Leegaard's newly described species of *Laboea* and its allies. The abundance of these small Infusoria as found by Gran from the Dutch waters does not agree with our records.

(1) *Lachymaria* sp. Only occurred once, water samples, May.

(2) *Coleps* sp. A small species shaped like a flower-pot with square ends, water samples, rare, August.

(3) *Tiarina fusus* Cl. and L. Fairly common in August and September, rare in July and October, chiefly in water samples.

(4) *Mesodinium* sp. Common in water samples.

(5) *Nassula* sp. Rare from May to August, water samples.

(6) *Strombidium caudatum* From. Rare in summer, water samples.

Genus LABOEA Lohmann.

The species of this genus, so far as I have seen, all have a yellow colour. They are common in the summer but occur all through the year although very rare in winter. Some of the most delicate of the Infusoria. Never found in the tow nettings.

(7) *Laboea conica* Lohm. The commonest species of the genus. Occurs fairly often through the summer, but never in large numbers.

(8) *L. strobila* Lohm. Occasionally from July to November and also in January

(9) *L. acuminata* Leegaard. Occasionally through the year, chiefly in May.

(10) *L. spiralis* Leegaard. Rare, May and July.

(11) *L.* sp. All through the year several unidentified species occurred, except for part of December and January.

(12) *Lohmanniella oviformis* Leegaard. Rare, only in August, water samples.

(13) *Euplotes vannus* O.F.M. Once only in July, water samples.

(14) *E.* sp. Rare, September, water samples.

(15) *Tintinnus subulatus* Ehr. From July to October, not uncommon, most frequent in August.

(16) *Tintinnopsis beroidea* (Stein). Very common, both in tow nettings and water samples, but especially in the former early in November, middle of December, end of March and again through July and August ; at other times not so frequent. Almost absent through October and the latter part of September.

(17) *T. campanula* (Ehr.). Occasionally at intervals from August to March, not observed from April to July. Both in tow nettings and water samples.

(18) *T. ventricosa* Cl. and L. Common at intervals throughout the year. Commonest in September. In both tow nettings and water samples, but commonest in the water samples.

(19) *Cittarocyclis denticulata* Ehr. Occasionally from August to October. This species is abundant close to the shore.

(20) *C. edentata* Brandt. Once only in October, water samples.

(21) Infusoria indet. Chiefly in the summer and early autumn in numbers.

THE METAZOA.

The Metazoa in the water samples being negligible the following is an account of the tow nettings examined as described above through the same period as the water samples and from the same locality.

CŒLENTERATA.

The medusæ are chiefly confined to the coarse and medium tow nets. Beginning at the end of January with *Phialidium hemisphericum* they continue for the rest of the year until nearly the end of November when they are absent for the winter. Ctenophores and Siphonophores represented chiefly by *Pleurobrachia pileus* and *Muggiœa atlantica* are common in the summer, although *Pleurobrachia* was not so numerous as usual this year, possibly owing to the April storms and the coldness of May and June.

The medusæ are specially interesting because they carry other animals parasitically and thus serve as effective transports. Those chiefly so utilised are *Cosmetira pilosella*, *Phialidium hemisphericum*, *Obelia* sp., *Turris pileata* and *Stomotoca dinema*; perhaps the species most frequently so used, and necessarily so as they are the commonest, are *Phialidium hemisphericum* and *Obelia* sp. *Phialidium* serves as host for larval trematodes, larval pycnogonids and larval *Peachia*. *Obelia* has not been noticed as a host for *Peachia* larvæ, probably because it is too heavy to be carried by so small a medusa. *Cosmetira* serves as host for all three, *Turris pileata* and *Stomotoca dinema* for larval trematodes. The trematodes are always the late cercaria stage of *Pharyngora bacillaus* (Molin), which reaches maturity in the mackerel (Lebour, J.M.B.A., 1915). This occupies the manubrium and mesoglœa. It is interesting in this connexion that E. T. Browne (P.Z.S., 1896) notes that a species of cercaria infects the mesoglœa of *Phialidium temporarium* (i.e. *P. hemisphericum*) in Valencia Harbour, and that *Halcampa* (i.e. *Peachia* larva) also selected this medusa, attaching itself to the generative organs. I find that *Halcampa* attaches itself to the medusa margin as well as the inside of the generative organs. The pycnogonid *Anaphia petiolata* Kröyer lives in the larval state tightly folded up in the manubrium of *Phialidium*, *Obelia* and *Cosmetira* (Lebour, J.M.B.A., 1915).

ANTHOMEDUSÆ.

"The Medusæ of the World," Mayer.

(1) *Steenstrupia rubra* Forbes. Begins in April and is common till the middle of June when it disappears.

(2) *Hybocodon prolifer* L. Ag. Begins at the end of March, is common through April, very common in May up to the middle, then dwindles and disappears in the beginning of June.

(3) *Sarsia prolifera* Forbes. Rare, in June only.

(4) *S. tuberosa* Lesson. Once only in June.

(5) *S. eximia* Allman. Once only in September.

(6) *Slabberia halterata* Forbes. Once only early in September.

(7) *Stomotoca dinema* L. Ag. Begins in July, is common through the month, becomes less common and disappears in November.

(8) *Turris pileata* (Haeckel). Fairly common now and then in June, July and August, rare in September and October.

(9) *Bougainvillia brittanica* Forbes. Once only in June.

(10) *Rathkea octopunctata* Haeckel. Begins in the middle of February, one of the first medusæ to appear, becomes very common in April and the beginning of May, disappears in the middle of June. It, however, reappears in September as a single specimen.

(11) *Willsia stellata* Forbes. Once only at the end of August.

LEPTOMEDUSÆ.

(12) *Obelia* sp. Medusæ extremely abundant. Begins at the end of February, very common from May to October, leaves off at the end of November and is absent through December, January and most of February.

(13) *Cosmetira pilosella* Forbes. Begins in May, very common on and off from June to September.

(14) *Clytia volubilis* Lamouroux. Once only in April.

(15) *Phialidium hemisphericum* (Gron.). Perhaps the commonest of the medusæ here. Begins at the end of January, is common from May to October and continues till the middle of November.

(16) *Saphenia gracilis* Forbes and Goods. Rare in May. On June 14th the nets were full of it and it was abundant once in August.

SEMÆOSTOMEÆ.

(17) *Chysaora* sp. Once in November.

(18) *Aurelia* sp. Ephyræ. One on January 24th. Continues fairly commonly from February to the beginning of April, then stops. One occurred on September 6th.

SIPHONOPHORA.

(19) *Muggiæa atlantica* J. T. Cunn. Once at the end of January, rare in February, but continues till September, when it is very common.

CTENOPHORA.

(20) *Pleurobrachia pileus* Fab. Fairly common, February to July, and from September to November, chiefly young forms.

(21) *Bolina infundibulum* Fab. On June 14th the nets were full of it with *Saphenia gracilis.* In October, 1915, it was fairly common.

(22) *Beroë cucumis* (Fab.). In October and November, 1915, and in May to August, 1916, rare.

ZOANTHARIA.

(23) *Arachnactis Bournei* Fowl. Larva of *Cerianthus Lloydii* Gosse. From March to June, common.

(24) *Peachia* sp. larva (=*Halcampa chrysanthellum* (Peach) of Haddon), common, May and June to the middle of July, on medusæ.

PLATYHELMINTHES.

Amongst these are some interesting larval trematodes which occur in the free state, having been captured probably in the interval of changing hosts. Also two parasitic in medusæ and in *Sagitta*, both of which eventually enter fish as their final host.

(1) *Pharyngora bacillaris* (Molin). What I believe to be the free-swimming tailed cercaria of this species occurred once in fair numbers on January 28th, 1916. It is described in a separate paper (p. 201) of this Journal. The late cercaria without a tail is found parasitic in medusæ and in *Sagitta*, besides being sometimes free in the sea at intervals throughout the year. Commonest in June.

(2) *Derogenes varicus* (O. F. Müll.). Occurs in *Sagitta bipunctata* in the late cercaria stage in June. In old material of previous years it is quite common.

(3) Turbellarian indet. Occurred occasionally in August and November.

NEMATODA.

Unidentified trematodes occurred occasionally free in the autumn and winter; a larval *Ascaris* (described in another paper of this Journal, p. 201) is common in *Sagitta bipunctata.*

ANNELIDA.

E. J. Allen, "Polychæta of Plymouth and the South Devon Coast, etc.," J.M.B.A., 1915.

The annelids with the exception of *Tomopteris* and *Autolytus* are all larval forms.

(1) *Autolytus longiferiens* De St. Joseph. Occurred once at the end of January with eggs, twice with eggs at the beginning of September, and one male.

(2) *A. rubropunctatus* (Grube). Once in September, 1915, twice in November, once in August and twice in September, 1916, always with eggs.

(3) *A. pictus* (Ehlers). Once in September and once in November, 1915. Once in September, 1916, always with eggs.

(4) *A.* sp. These were allied to *A. Edwarsi*, a small species, three with eggs and one male, always in September.

(5) *Polynoë* sp. juv. Once in December and once in the end of March.

(6) Spionid larva, occasionally from November to March. Rarely in May and July.

(7) *Magelona* sp. larva. Fairly common in July and August.

(8) *Pœcilochætus serpens* Allen, larva. Occurred in small numbers every month except December and April. Commonest in May and August.

(9) *Cirratulus* sp. juv. Once only early in March.

(10) Terebellid larva. Present every month, but not usually in large numbers except once in November, then rare till the end of February, when it increases and is very common in May. The houses of the very young larvæ are extremely pretty, the animal using all sorts of small organisms to cover itself, especially

diatoms, but sometimes the case is entirely of sponge spicules. As the worm grows the house becomes transparent and hyaline.

(11) *Pectinaria* sp. larva. Only found rarely in October and December.

(12) Annelid larvæ indet. Occurred occasionally but particularly from January to the end of March when they were at times abundant in very young stages.

(13) *Tomopteris heligolandicus* Greef. Begins in the middle of June and is very common in July, rare in September and October. Young forms chiefly from July to September.

CHÆTOGNATHA.

Sagitta bipunctata (Q. & G.). Present throughout the year, scarce in most of March, April, May and June. Very common most of the rest of the year.

POLYZOA.

Cyphonautes larva. Fairly common from September to the end of March, rare from April to August. Commonest at the end of March.

PHORONOIDEA.

Actinotrocha larva. Only seen in July and September, 1916. More common in 1915.

ROTIFERA.

Synchæta sp. Rare, September, October and March.

CRUSTACEA.

Copepoda.

Sars, G. O., "Crustacea of Norway, Copepoda."

(1) *Calanus finmarchicus* Gunner. Common on and off from the end of April to the beginning of November, generally present in small numbers at other times.

(2) *Paracalanus parvus* Claus. Unusually scarce this year except at certain times. Very common in May, common parts of August, September and October. Very common for part of November, then becomes rare or absent.

(3) *Pseudocalanus elongatus* Boeck. Perhaps the commonest copepod here. Exceedingly common all through the year except from the middle of May to the end of July, when it becomes rarer and is sometimes absent.

(4) *Centropages typicus* Kröyer. Common in September and October, 1915, scarce or absent through the winter, rather more abundant in May, becoming rare again in August.

(5) *C. hamatus* Lillj. Common in September and October, 1915, then absent until August, when it is very common on the 16th.

(6) *Isias clavipes* Boeck. Fairly common in May, rare in June.

(7) *Temora longicornis* Müller. Very common all through the summer and in the middle of February, common in parts of November, but rather rare in winter.

(8) *Anomalocera Patersoni* Templeton. From September to the beginning of November; not common.

(9) *Labidocera Wollastoni* Lubb. Not common, in July.

(10) *Candacia armata* Boeck. Rare through the winter, common in July and September.

(11) *Parapontella brevicornis* Lubb. Common in February and March and occasionally in May, otherwise rare; absent from October to February.

(12) *Acartia clausii* Giesbr. I find this species of *Acartia* the only one present in 1916. It is exceedingly abundant most of the year, very common on and off from May to the beginning of January and very seldom absent altogether.

(13) *Longipedia Scotti* G. O. Sars. Once only in February.

(14) *L. minor* Scott. Once in water samples and once in the tow nets, June.

(15) *Euterpina acutifrons* (Dana). Rare, October to December.

(16) *Idyæa furcata* Baird. Once only in December.

(17) *Amphiascus similis* Claus. Rare, September and October.

(18) *Oithona similis* Claus. More or less common throughout the year except from November to January. Very common in the middle of February and the middle of May.

(19) *O. nana* Grubb. Rare, January to May.

(20) *O. plumifera* Baird. Rare, from February to May, and in September.

(21) *Coryceus anglicus* Lubb. Present most of the year, but rarest in the summer. Through October and November it agrees with *Pseudocalanus* in its abundance, but becomes scarce in December.

(22) *Thaumaleus longispinosus* Brown. Once only in September, 1915, with eggs.

(23) *Caligus rapax* M. Edw. Free in the tow nettings in September, December and March. On one occasion a female with eggs was present; an unusual occurrence in the free state.

Copepod nauplii are common on and off for most of the year. At the end of January they were very abundant, also at the end of May and beginning of July. *Calanus* and *Temora* are the commonest forms identified.

CIRRIPEDIA.

"Nordisches Plankton," Vol. 11.

Balanus nauplii occur in the beginning of February, are very common in the middle of February and continue till the beginning of May, when they dwindle and disappear except for a straggler or two in June. In the end of July they reappear and stay till the beginning of October. Cypris stages begin in the end of April and continue until the end of May, are rarer in June and disappear in July. A few were seen in September and February. The fact that there are two seasons for these larvæ (which is borne out by other Plymouth records) probably means that the July forms are a different species, as at Port Erin only the spring larvæ occur.

CLADOCERA.

"Nordisches Plankton," Vol. 1.

(1) *Evadne Nordmanni* Lovén. Begins in the end of April and grows very common in May, is common through the summer until the middle of September when it disappears.

(2) *Podon intermedius* Lillj. Very similar in occurrence to *Evadne*, but is more frequent in August and September.

AMPHIPODA.

Sars, G. O., "Crustacea of Norway, Amphipoda."

(1) *Apherusa bispinosa* (Bate). Occurred once in October and once in January.

(2) *A. Clevii* Sars. A few specimens once in August and twice in June.

(3) *Caprella* sp. Once at the end of August.

Amphipoda indet. Rarely in April and September.

ISOPODA.

"Nordisches Plankton," Vol. 14.

(1) *Idotea viridis* (Slabber). Rare in November and March.

(2) *Gnathia maxillaris* (Mont.). Young larva, free, rare, December. Praniza larva once in the middle of May.

(3) *Microniscus* sp. On Copepods, chiefly *Calanus*, *Acartia* and *Pseudocalanus*, from September to December, rare in March, most frequent in September.

(4) *Bopyrina* sp. Rare, January and February.

CUMACEA.

Sars, G. O., "Crustacea of Norway, Cumacea."

(1) *Pseudocuma cercaria* (P. G. van Ben). Very rare, September and February.

SCHIZOPODA.

"Nordisches Plankton," Vol. 12.

(1) *Nyctiphanes Couchii* T. Bell. Not common, in the beginning of May only, immature.

(2) *Macropsis Slabberia* Van Ben. Rare, December only.

(3) *Siriella Clausii* G. O. Sars. Once only in October.

(4) *Leptomysis mediterranea* G. O. Sars. Not common, November to January.

Euphausiidæ larvæ. Not common, October, November, March to May and August.

STOMATOPODA.

Squilla Desmaresti Risso, larva. Once only in October, 1915.

MACRURA.

These are all larval forms; starting with *Carcinus mœnas* early in January they gradually increase and are very common through the spring and early summer, and although plentiful through August and September, fall off considerably in October, being only represented by stray stragglers through the winter.

(1) *Leander* sp. larva. On and off from May to November. Single specimens at the end of February. Commonest in July.

(2) *Galathea* sp. larva (Sars, G. O., "Bidrag til Kundskaben om Decapodernes Forhandlingar," Arch. Math. Naturw., 13, 1889–90). Begins at the end of January and continues common till May, when it dwindles and disappears in September, commonest in March.

(3) *Eupagurus* sp. larva (Sars, *ibid.*, 1889–90). Very rare at the beginning of January, continues rare through March to the end of April when it is common, continues fairly common till the middle of May, rare from June to October. Older stages occasionally in the summer.

(4) *Hippolyte* sp. larva (Sars, "Account of the Postembryonal Development of Hippolyte varians Leach," Arch. Math., etc., 32, 1911). Common June to September, specially abundant in September, continues into November, and was found twice in December, rare in the spring.

(5) *Crangon vulgaris* L. larvæ (Sars, "Bidrag til Kundskaben om Decapodernes Forhandlingar," Arch. Math., etc., 14, 1890). From February to September, never very common.

(6) *Ægeon fasciatus* Risso, larva (Gurney, R., "The Metamorphoses of the Decapod Crustaceans Ægeon (Crangon) fasciatus, etc.," P.Z.S., Vol. II, 1903). One specimen in January. On and off from May to September.

(7) *Ceraphilus nanus* (Kröyer), larva (Sars, *ibid.*, No. 14). Rare, September and October.

Crangonidæ larvæ indet. Occurred occasionally from June to October.

Other Macruran larvæ indet. chiefly allied to *Hippolyte*, common in July and August.

(8) *Jaxea noctiana*, *Trachilifer* larva (Bouvier, J.M.B.A., X, N.S., 1913). Occurred once on August 16th, 1916. Unusual to find it so far inland.

BRACHYURA.

(9) *Porcellana* sp. zoea (Sars, *ibid.*, 13). One specimen on March 23rd, then begins at the end of April and in June and July is very common, continues till the middle of October.

(10) *Eurynome aspera* (Penn.) zoea (Cano, G., "Sviluppo œ Morphologia degli Oxyrhynchi," Mitt. Zool. Stat. Neapel, X, 1893). Rare, March and July.

(11) *Cancer pagurus* L. zoea (Pearson, J., "Memoir on Cancer the Edible Crab," 16th Lancs Sea Fish. Lab. Rep. for 1907). From the middle of January to March, common.

(12) *Portunus* sp. zoea (Williamson, C. H., "Report on Larval and Later Stages of Certain Decapod Crustacea," 28th Ann. Rep. Fish. Board Scotland, 1907). Many species, begin early in March, become very common in April and continue till September, less common from October to November, after which they disappear.

(13) *Carcinus mœnas* Leach zoea (Williamson, C. H., "On the Larval and Early Young Stages and Rate of Growth of the Shore Crab" (Carcinus mœnas Leach) 21st Ann. Rep. of Fish. Board for Scotland, 1903). The first of the Brachyura larvæ to appear, arrives early in January, is specially abundant in February and continues till May, after that very scarce.

(14) *Corystes cassivelaunus* (Penn.) zoea (Gurney, R., "The Metamorphosis of Corystes cassivelaunus (Penn.)," Q.J.M.S., 1903). From the middle of February to July, fairly common, rare in September.

Brachyura zoea indet. With a long spine like Corystes fairly common in September.

Megalopa indet. Scarce, from May to November.

PYCNOGONIDA.

Norman, A. M., "The Podosomata (=Pycnogonida) of the Temperate, Atlantic and Arctic Oceans," J. of the Linn. Soc. Zool., Vol. XXX.

(1) *Anaphia petiolata* (Kröyer) juv. In June, September and October free, with the hind legs not fully developed. In the larval stage living in medusæ common from July to September.

(2) *Pallene brevirostris* Johnston. Occurred once at the end of October.

MOLLUSCA.

Polycera quadrilineata (Müll.). Once only in September, 1915.

Larval *Gasteropoda.* On and off nearly all the year, commonest in July. Rare in mid-winter.

Larval *Lamellibranchiata.* On and off, not very common for most of the year. Commonest in September, rare in winter.

Limacina balea Müller *retroversa* (Flemm.). Common in the middle of September, 1915. Occurred occasionally from July to October. Common once in August, 1916.

ECHINODERMATA.

Holothurian juv. Rare in December and January.

Ophiopluteus. Begins in March, very common towards the end of the month, dwindles in April and disappears in May. Occurs again in August and September, common in September.

Echinopluteus. A few occurred once in the middle of November, 1915, begins in May, not common. Very common at intervals in July and August.

Auricularia. Rare, January and February.

Very young Echinoderm larvæ in March.

TUNICATA.

Oikopleura dioica Fol. Common from February to May and from August to September, otherwise not very common and occurring at intervals. Commonest in early April and early August.

Appendicularian indet. Rare in August till November, and in February.

Fish eggs and young fish were occasionally present.

A Survey of the Plankton in each month both from water samples and tow nets.

1915. *September* (21st to 30th).

Winds mainly S. and S.E. Weather fairly fine. Shows both groups of diatoms. *Coscinodiscus* species, *Biddulphia mobiliensis* and *regia* beginning, *Rhizosolenia* which is almost at the end of its season not common except *R. Stolterfothii,* which is still abundant. *Skeletonema, Chætoceras constrictum* and *Asterionella* common, *Paralia* fairly common. Very few Peridiniales except *Prorocentrum micans* which is near its maximum and *Ceratium fusus.* Of the other unicellular groups *Laboea* species occur in small numbers, *Tintinnopsis ventricosa* is abundant and *Pontosphæra Huxleyi* occurs singly several times.

Of the Cœlenterates *Phialidium hemisphericum* and *Obelia* medusæ with young *Pleurobrachia* are common, but no other species. Amongst the Annelids *Autolytus longiferiens* and *rubropunctatus* occur singly with eggs and a few larvæ of various kinds are present. *Sagitta* is very common, *Cyphonautes* present but not abundant.

Many copepods occur, *Acartia, Calanus* and *Pseudocalanus* are the commonest, also common are *Centropages typicus* and *hamatus* and *Temora* and *Coryceus* is common at the end of the month. Brachyura zoeæ and the larva of *Hippolyte* are common, *Porcellana* zoeæ and *Podon intermedius* are common in the middle of the month and dwindle or disappear at the end. *Limacina balea* f. *retroversa* was common once in the middle of the month.

Chief forms—*Asterionella japonica, Chætoceras constrictum, Rhizosolenia Stolterfothii, Skeletonema costatum, Prorocentrum micans, Phialidium hemisphericum*, Obelia sp., *Sagitta bipunctata, Calanus finmarchicus, Pseudocalanus elongatus, Acartia Clausii, Centropages typicus*, Brachyura zoeæ and *Hippolyte* larvæ.

October.

S.E. winds prevalent. Chiefly fine weather. *Asterionella* common until the middle, then dwindles and disappears. *Biddulphia* species not yet common. *Chætoceras* species common at the beginning and fall off in numbers towards the end, *Lithodesmium undulatum* common until the middle, *Mastigloia* sp. very abundant from the middle to the end of the month.

Nitzschia closterium common. *Paralia* on the increase. *Rhizosolenia Stolterfothii* common at the beginning but absent at the end. *Skeletonema* common and *Streptotheca thamensis* present with it nearly all the month. Of the Peridiniales *Ceratium bucephalum* is fairly common, *C. fusus* present in small numbers, *Prorocentrum micans* continually present, *Peridinium divergens* sometimes fairly common.

Laboea species still present in small numbers, and *Tintinnopsis ventricosa*, *Pontosphæra* more frequent, very common at the end of the month. Of the Cœlenterates *Stomotoca dinema* and *Turris pileata* occur although only *Phialidium hemisphericum* and *Turris pileata* are common. Besides *Pleurobrachia* which is sometimes common, *Beroë* and *Bolina* both occur. Annelid larvæ rare. *Sagitta* very common, *Cyphonautes* continues but is rare.

Of the copepods *Calanus* is still common, but *Pseudocalanus, Temora* and *Acartia* are the commonest; *Coryceus* is also very common and seems to follow *Pseudocalanus* closely in numbers, *Centropages typicus* and *hamatus* fall off in numbers. All the larval Crustacea are much less numerous.

Chief forms—*Asterionella japonica, Chætoceras constrictum, convolutum* and *densum* at the beginning, *Mastigloia* sp. from the middle of the month, *Nitzschia closterium, Skeletonema costatum, Ceratium bucephalum, Prorocentrum micans, Phialidium hemisphericum, Obelia* sp., *Sagitta bipunctata, Calanus finmarchicus, Temora longicornis, Pseudocalanus elongatus, Coryceus anglicus* and *Acartia Clausii.*

November.

N.E. winds prevalent. Mostly cold.

Asterionella much reduced in numbers. *Biddulphia mobiliensis* and *regia* both come on and are very common from the middle to the end of the month. *Chætoceras* species greatly reduced, almost disappearing. *Guinardia* common towards the end of the month, also *Hyalodiscus stelliger*, *Mastigloia* sp. in large numbers at the beginning, absent after the 8th. *Paralia* becomes abundant, *Skeletonema* very common with *Streptotheca* common also. *Ceratium bucephalum* and *Prorocentrum micans* much scarcer, the latter absent altogether at the end of the month. *Tintinnopsis beroidea* very common at times through the month. Hardly any cœlenterates except *Phialidium* and *Obelia*, and these disappear at the end of the month. *Autolytus pictus* and *rubropunctatus* appear with eggs. *Sagitta* very common, copepods abundant, *Calanus* becoming scarce, *Centropages* almost absent, *Paracalanus* common, *Acartia*, *Pseudocalanus* and *Coryceus* very common. Crustacea larvæ practically absent.

Chief forms—*Biddulphia* species, *Guinardia flaccida*, *Hyalodiscus stelliger*, *Mastigloia* sp., *Paralia sulcata*, *Skeletonema costatum*, *Streptotheca thamensis*, *Tintinnopsis beroidea*, *Sagitta bipunctata*, *Paracalanus parvus*. *Pseudocalanus elongatus*, *Acartia Clausii* and *Coryceus anglicus*.

December.

S.W. winds prevalent. A good deal of overcast and showery weather.

Biddulphia mobiliensis very common, *regia* not so common, *sinensis* rare. *Chætoceras* almost absent, *Coscinodiscus* species begin to be common, especially *C. excentricus*, *Rhizosolenia Stolterfothii* which has been dwindling in numbers disappears at the end of the month. *Skeletonema* common early, rare at the end of the month. All Peridiniales rare. *Tintinnopsis beroidea* common till the middle of the month. Copepods scarce except *Pseudocalanus* and *Acartia*, *Calanus* rare and absent for a large part of the month.

Chief forms—*Biddulphia mobiliensis*, *Coscinodiscus excentricus*, *Skeletonema costatum*, *Tintinnopsis beroidea*, *Sagitta bipunctata*, *Pseudocalanus elongatus* and *Acartia Clausii*.

1916. *January.*

Nearly all S. and S.W. winds. Weather mostly fine.

Biddulphia mobiliensis and *regia* common. *Coscinodiscus excentricus* common, *Paralia* common, *Skeletonema* rare until the end of the month when it becomes common again. *Streptotheca* following it in much the same abundance, *Thalassiothrix* common at the end of the month. Peridiniales practically absent. One specimen of *Muggiœa atlantica* at the end of the month, one *Aurelia* ephyra on the 24th. *Sagitta* very common. Copepods rare except *Pseudocalanus*, nauplius stages increase and are very common at the end of the month, zoea stage of *Carcinus mœnas* and *Cancer pagurus* begins in the middle of the month. *Galathea* larva begins at the end. Young fish and fish eggs present.

Chief forms—*Biddulphia mobiliensis* and *regia*, *Coscinodiscus excentricus*, *Paralia sulcata*, *Sagitta bipunctata*, *Pseudocalanus elongatus*, copepod nauplii, Brachyura zoeæ and *Galathea* larvæ in the second half of the month.

February.

S. and S.W. winds at the beginning, N.E. at the end. Stormy weather mostly till the end of the month.

Biddulphia mobiliensis and *regia* common, *sinensis* more frequent. *Chætoceras* begins again at the end of the month, *C. curvisetum*, *convolutum* and *teres* common. *Coscinodiscus excentricus* common, *radiatus* fairly common. *Paralia* common, *Skeletonema* and *Streptotheca* very common. *Thalassiothrix* common at the end of the month. Practically no Peridiniales. Single specimens of *Phialidium* and *Obelia*. *Rathkea octopunctata* becomes common at the end of the month. Ephyræ of *Aurelia* present on the 10th and increase at the end of the month. *Pleurobrachia* and *Muggiœa* present. *Sagitta* not so common, Terebellid, larvæ fairly common, *Cyphonautes* larvæ fairly common on the 10th.

Copepods common up to the 17th, then scarce, probably owing to the N.E. winds coming on. *Calanus* rare, *Temora* and *Oithona similis* very common on the 17th, *Pseudocalanus* common all the month. *Parapontella brevicornis* at the latter end, *Carcinus mœnas* zoea very common. *Galathea* larva common, *Crangon vulgaris* larva fairly frequent. *Corystes* zoea begins and *Levander*. Copepod nauplii fairly common and *Balanus* nauplii very common, beginning on the 5th. *Oikopleura dioica* fairly common.

Chief forms—*Biddulphia mobiliensis* and *regia*, *Coscinodiscus excentricus* and *radiatus*, *Paralia sulcata*, *Skeletonema costatum*, *Streptotheca thamensis*, *Temora longicornis*, *Oithona similis*, *Carcinus mœnas* zoea, *Galathea* larva, *Balanus* nauplius and *Oikopleura dioica*.

Here we find a rush of larval Crustacea especially towards the end of the month.

March.

Prevailing winds N.E. and N. with S.W. in the middle and end. Weather usually cold.

Biddulphia mobiliensis very common, *regia* not so common, *sinensis* increasing. *Chætoceras curvisetum* very common, *teres* and *convolutum* common. *Coscinodiscus excentricus* common, *radiatus* not so common. *Ditylium Brightwelli* common at times, *Rhizosolenia Shrubsolei* begins to be abundant in the middle and is very common in the end, *Paralia* fairly common through the month, *Skeletonema* and *Streptotheca* very common, *Thalassiosira gravida* begins to be fairly common in the middle and becomes very common at the end, the same with *Thalassiothrix. Tintinnopsis beroidea* is very common at the end of the month. A few *Phialidium* and *Obelia* medusæ present. *Rathkea octopunctata* occurs the whole month, getting common towards the end. *Hybocodon prolifer* begins in the middle and gets common towards the end. Terebellid larvæ are common through the month. *Poecilochætus* larva rare, *Sagitta* occurs all through the month but is not common. *Cyphonautes* very common at the end of the month.

Copepods not very abundant except *Pseudocalanus*, which is very common, *Calanus* rare but present throughout the month, *Acartia*, *Temora* and *Parapontella* fairly common, *Carcinus mœnas* zoea common at the beginning but absent towards the end, *Portunus* sp. zoea begins. *Corystes* zoea occurs through the month but is not common, *Galathea* larva common at the beginning, rare towards the end, *Crangon vulgaris* larva through the month but not common. Copepod nauplii increase at the end of the month. *Balanus* nauplii very common all through the month. Larval Gasteropoda all through the month, common at the end. Larval Lamellibranchiata not so common. *Ophiopluteus* larvæ through the month, common at the end, *Auricularia* larva present once at the beginning. *Oikopleura* fairly common through the month. Young fish rare, fish eggs fairly common.

Chief forms—*Biddulphia mobiliensis*, *Chætoceras curvisetum*, *teres* and *convolutum*, *Coscinodiscus excentricus*, *Skeletonema costatum*, *Streptotheca thamensis*, *Rathkea octopunctata*, Terebellid larvæ, *Pseudocalanus elongatus*, *Balanus* nauplius, *Ophiopluteus* larvæ and *Oikopleura dioica*.

April.

Winds N., E. and S. South at the end. Between 10th and 25th so strong that no samples were taken, after that S. wind and abundant plankton. All calm many days when the samples were taken after the storms.

Biddulphia mobiliensis not so common, *regia* rare, *sinensis* more common, *Lauderia* common, *Nitzschia delicatissima* common at the end, *Skeletonema* very common, *Streptotheca* very common at the beginning, rare at the end, *Thalassiosira gravida* common. *Ceratium fusus*, *Peridinium* spp. and *Prorocentrum* not very common but occur throughout the month. *Phæocystis* very common at the end. *Phialidium* and *Obelia* become common at the end of the month, *Steenstrupia rubra* and *Clytia volubilis* occur rarely, *Rathkea octopunctata* very common, *Arachnactis*, *Muggiæa* and *Hybocodon* occur through the month but not commonly except *Hybocodon* at the end of the month. Terebellid larvæ fairly common, *Sagitta* rare.

Calanus very common at the end of the month, *Temora and Pseudocalanus* very common. *Portunus* sp. zoea very common, copepod nauplius and *Balanus* nauplius very common. Cypris stage of *Balanus* begins at the end of the month. Young fish and fish eggs rare.

Chief forms—*Chætoceras curvisetum*, *Lauderia borealis*, *Skeletonema constatum*, *Thalassiosira gravida*, *Rathkea octopunctata*, *Temora longicornis*, *Pseudocalanus elongatus*, *Portunus* sp. zoea, *Balanus* and copepod nauplii.

May.

Prevailing winds S. and S.W. Sometimes E. and N.W. Weather variable, fine at the end with S. and S.W. winds.

Chætoceras species common, especially *C. curvisetum* and *pseudocrinitum*, *Lauderia* very common at the beginning, dwindles at the end of the month. *Mastigloia* sp. in large numbers from the middle to the end of the month, *Nitzschia delicatissima* very common, *Rhizosolenia* species increasing, *R. Shrubsolei* very common, *R. Stolterfothii* gradually increasing so that it is very common at the end of the month, *R. hebetata* and *semispina* very common from the middle to the end of the month, *R. alata* occurs through the whole month but is not common. *Skeletonema* very common. *Thalassiosira gravida* common. Various Peridiniales occur but not in large numbers. Infusoria too in small numbers abound. *Phæocystis Pouchetii* is very common through the whole month. Amœbæ fairly common. *Phialidium* and *Obelia* are very common and various other medusæ are present. *Sagitta* is not common and disappears at the end of the month. *Calanus*, *Temora*, *Acartia* and *Pseudocalanus* are abundant, *Paracalanus* very common early in the month, several other copepods present in smaller numbers. *Portunus* sp. zoea is common, Megalopa stages appear in the middle of the month. Various other Crustacea larvæ are present, of these *Eupagurus*, *Porcellana* and *Corystes* are common. *Evadne Nordmanni* and *Podon intermedius* are common in the middle of the month, copepod nauplii are common and *Balanus* nauplii very common in the beginning, the cypris stages being commoner in the middle of the month when they abound.

Chief forms—*Skeletonema costatum*, *Rhizosolani Shrubsolei*, *Stolterfothii* and *hebetata* f. *semispina*, *Mastigloia* sp., *Thalassiosira gravida*, *Lauderia borealis*, *Chætoceras curvisetum*, *Phæocystis Pouchetii*, *Phialidium hemisphericum*, *Obelia* sp., *Calanus finmarchicus*, *Temora longicornis*, *Acartia Clausii*, *Pseudocalanus elongatus*, *Portunus* sp., zoeæ and *Balanus* nauplii and cypris stages.

June.

Prevailing winds N., S. at end of month. Weather mostly cold and dull.

Cerataulina Bergoni fairly common at the beginning, *Chætoceras* dwindles but *C. curvisetum* and *pseudocrinitum* are still common at the beginning and an undetermined species is common through the month particularly in the tow nets. *Leptocylindrus danicus* is fairly common and *Mastigloia* is occasionally present in large numbers. *Nitzschia delicatissima* is very common till the middle of the month and falls off towards the end. *Paralia* is rare, Rhizosolenia species very common, *R. Shrubsolei* and *Stolterfothii* very common through the month, *R. hebetata* f. *semispina* very common towards the end, *R. alata* gradually increasing, to be very common in the middle and continuing so till the end of the month. *Skeletonema* not common. *Thalassiosira gravida* rare. Maximum of the Peridiniales. *Amphidinium crassum* begins, *Ceratium fusus* fairly common, *Dinophysis* species, *Diplopsalis pillula*, *Glenodinium bipes*, *Gymnodinium rhomboides*, *Pouchetia armata*, *Spirodinium spirale* and *glaucum* all at a maximum. Various species of *Peridinium* fairly abundant. Various Infusoria occur, although never in large numbers. *Phæocystis* very common till the middle of the month when it disappears. Medusæ abound, especially *Phialidium* and *Obelia*. On the 14th *Saphenia gracilis* was very abundant, and with it a large number of *Bolina infundibulum*. The day was cold and dull with a north wind. On the same day *Spirodinium glaucum* and *Dinophysis acuminata* were at a maximum. The larva of Peachia sp. (Halcampa) was very common on medusæ. *Sagitta* rare.

Copepods not very abundant, *Calanus*, *Temora* and *Acartia* common. *Pseudocalanus* very rare, *Portunus* sp. zoea very common, Megalopa stages fairly common, larvæ of *Hippolyte* and *Porcellana* very common on the 21st. Copepod nauplii not so common, *Balanus* cypris stage disappears after the beginning of the month. *Anaphia petiolata* and larval Gasteropoda common at the end of the month.

Chief forms—*Guinardia flaccida*, *Rhizosolenia* species, *Glenodinium bipes*, *Gymnodinium rhomboides*, *Pouchetia armata*, *Spirodinium spirale* and *glaucum*, *Phialidium hemisphericum*, *Obelia* sp., *Calanus finmarchicus*, *Temora longicornis*, *Acartia Clausii*, *Portunus* sp. zoea, *Hippolyte* and *Porcellana* larvæ.

July.

S. and S.W. winds prevail. Fairly fine most of the month.

Asterionella very common all the month. *Chætoceras constrictum* very common, *C. curvisetum*, very common at the end of the month only. *Guinardia* very common in the middle, not so common at the beginning and end of the month. *Rhizosolenia* species very common, *R. alata* and *R. Stolterfothii* very common all the month, *R. Shrubsolei* not so common, *R. setigera* begins and gradually gets common, being very common at the end of the month. Peridiniales not so numerous. *Ceratium fusus* very common in the middle of the month. *Prorocentrum* increasing. Infusoria fairly common, especially *Tintinnopsis beroidea*, which at times is exceedingly abundant. *Phialidium* and *Obelia* very common. Other medusæ scarce. *Calanus*, *Temora*, *Acartia* and *Pseudocalanus* very common. *Portunus* sp. zoea and *Porcellana* zoea very common. Copepod nauplii common. *Echinopluteus* common at the end of the month.

Chief forms—*Asterionella japonica*, *Chætoceras constrictum*, *Rhizosolenia* species, *Ceratium fusus*, *Tintinnopsis beroidea*, *Phialidium hemisphericum*, *Obelia* sp., *Portunus* and *Porcellana* zoeæ.

August.

Prevailing winds S., some E. and some W. Mostly fine weather.

Second diatom maximum at the beginning of the month caused chiefly by *Mastigloia*, *Asterionella*, *Chætoceras*, *Lauderia*, *Rhizosolenia* and *Skeletonema* which are all very common. *Chætoceras constrictum* the commonest. *C. didymum* very common on the 10th. *Lithodesmium* scarce at the beginning but very common at the end of the month. *Rhizosolenia alata* is very common until after the middle when it becomes scarce and very rare at the end of the month. *R. hebetata* f. *semispina* very common at the beginning, disappears at the end, *R. setigera* very common after the middle but scarce at the end, *R. Stolterfothii* very common for the whole month. *Skeletonema* very common for most of the month, Peridiniales fairly frequent, especially *Prorocentrum micans*. Infusoria fairly abundant, especially *Tintinnus subulatus* and *Tintinnopsis beroidea*. *Dictyocha* and *Distephanus* begin in the middle of the month, *Phialidium* and *Obelia* very common. *Muggiæa atlantica* becomes common at the end of the month. Copepods abundant. *Calanus*, *Centropages typicus* and *hamatus* fairly common, *Acartia* and *Pseudocalanus* very common, *Candacia armata*, *Coryceus* and *Paracalanus* common at times. Brachyura zoeæ and other crustacea larvæ rare. *Evadne Nordmanni* and *Podon intermedius* common. *Balanus* nauplii very common at times. Echinoplutei very common on the 10th, Ophioplutei fairly common through the month. *Oikopleura* fairly common.

Chief forms—*Asterionella japonica*, *Chætoceras constrictum*, *Rhizosolenia Stolterfothii*, *Ceratium fusus*, *Prorocentrum micans*, *Tintinnus subulatus*, *Tintinnopsis beroidea*, *Phialidium hemisphericum*, *Obelia* sp., *Acartia* and *Pseudocalanus*, *Evadne Nordmanni* and *Podon intermedius*.

September (till the 18th).

Prevalent winds W. and N.W. Usually fine weather.

Asterionella much scarcer, *Chætoceras curvisetum* very common again, other *Chætoceras* species not so common. *Lithodesmium* and *Lauderia* fairly common. *Rhizosolenia* species rare except *R. Stolterfothii*, *Skeletonema* still very common. Peridiniales scarce except *Ceratium fusus* and *Prorocentrum micans* which is at its maximum. Infusoria fairly abundant, especially *Tintinnopsis* species. *Dictyocha* and *Distephanus* at their maximum. Few medusæ except *Phialidium* and *Obelia*. *Muggiœa* very common. *Sagitta* common.

Copepods fairly abundant, *Calanus* and *Temora* common, *Acartia* and *Pseudocalanus* very common. Various crustacea larvæ in small numbers, *Evadne* disappears at the beginning, *Podon* is common through the month. Copepod and *Balanus* nauplii very common. *Lamellibranchiata* larvæ common at times. Ophioplutei very common.

Chief forms—*Chætoceras curvisetum*, *Rhizosolenia Stolterfothii*, *Skeletonema costatum*, *Prorocentrum micans*, *Tintinnopsis beroidea*, *Muggiœa atlantica*, *Acartia*, *Clausii*, *Pseudocalanus elongatus*, *Podon intermedius*, *Ophiopluteus*.

The dates on which the plankton samples were taken, with wind and weather, morning tide and time at which taken. * Indicates that the samples were taken from the west channel. P Indicates preserved samples.

1915.		Weather.	Wind.	Greenwich time.	Morning tide.
September 21	P	fine	E.	11.30 a.m.	4.7
*23	P	drizzling	S.	abt. 11 a.m.	5.38
*25	P	fine	S.	12 noon	6.49
27	P	fine	N.W.	12 noon	7.45
29	P.	showery	N.	11.30 a.m.	8.40

		Weather.	Wind.	Greenwich time.	Morning tide.
October	1 P.	cloudy	S.S.W.	11 a.m.	9.41
	*4 P	overcast	S.S.E.	12 noon	1.10
	6	fine	S.S.W.	abt. 11 a.m.	3.37
	11	very fine	S.	12 noon	7.5
	13	fine	S.S.W.	abt. 11 a.m.	8.25
	15	unsettled	N.E.	abt. 11 a.m.	9.58
	*18	very fine	W.N.W.	abt. 12 noon	1.28
	*21	heavy showers	S.S.W.	abt. 11 a.m.	4.28
	27	calm	E.N.E.	11.30 a.m.	7.44
	29	fine, dry	E.N.E.	12.20 p.m.	8.25
November	1	dull, gusty	E.S.E.	11 a.m.	11.45
	3	fine, clear	E.N.E.	11.45 a.m.	1.49
	5	fine, cold	N.N.E.	11.45 a.m.	3.44
	8	cloudy, rain	S.W.	11 a.m.	5.59
	*11	rough, rain	S.	11 a.m.	8.18
	15	calm, cold	E.	12 noon	12 noon
	17	fine, cold	E.	12.45 p.m.	2.8
	19	cold, clear	E.	11.10 a.m.	3.52
	22	cold, dull	N.E.	11.15 a.m.	5.52
	24	fine, cold	E.N.E.	11.40 a.m.	6.58
	26	misty, smooth	N.E.	11.45 a.m.	8.2
	29	wet, rough	S.S.E.	11.40 a.m.	9.15
December	2	wet, rough	E.	12.15 p.m.	0.27
	9	wet, rough	S.S.W.	11.30 a.m.	7.23
	13	fine, cold	N.N.W.	11.30 a.m.	10.38
	16	fine, cold, showery	E.N.E.	12.25 p.m.	1.8
	*20	misty, calm	N.	11.30 a.m.	4.53
	22	misty, warm, smooth	S.W.	11.30 a.m.	6.13
	*29 P	strong wind, rain	S.	11.30 a.m.	10.23
1916.					
January	3 P	sunny, heavy swell	S.W.	11.30 a.m.	3.36
	* 5 P	sunny, sea mod.	—	11.30 a.m.	5.34
	8 P	fair	N.W.	11.30 a.m.	8.5
	11 P	dull, warm	—	11.30 a.m.	10.45
	*11	fair	W.	2.5 p.m.	noon
	18	swell	S.W.	2.45 p.m.	4.3
	24	fine	W.	11.25 a.m.	8.12
	*26	nasty sea	S.W.	11.20 a.m.	9.38
	28	fine	S.	11.15 a.m.	10.39
	31	dull	N.E.	11.40 a.m.	1.35

		Weather.	Wind.	Greenwich time.	Morning tide.
February	5	heavy sea	S.	11.35 a.m.	7.7
	*8	cold, clear	S.W.	11.40 a.m.	8.59
	10	dull, cold	S.W.	11.20 a.m.	10
	17	cold, sunny, nasty sea	S.W.	11.30 a.m.	4.54
	*21a	stormy	N.E.	10.45 a.m.	7.22
	25	snow showers	N.E.	11.10 a.m.	9.32
	28	fine	N.E.	11 a.m.	noon
March	1	fine, smooth	E.	11.15 a.m.	3.55
	8	snow showers	N.	11.5 a.m.	8.22
	*10	cold, rough	N.E.	11 a.m.	9.21
	14	stormy	E.	10.50 a.m.	0.31
	16	fine	S.W.	noon	3.21
	21	misty, calm	N.	noon	6.52
	23	cold, calm	N.	11.10 a.m.	8.1
	27	cold, wet	S.E.	11.10 a.m.	11.4
	29	cold, sunny	S.W.	11.30 a.m.	1.21
	31	calm, dull	S.	12.20 p.m.	4.1
April	4	calm, sunny	N.	11 a.m.	6.49
	6	calm, sunny	E.	11.50 a.m.	7.50
	10	calm, sunny	S.	11.50 a.m.	10.5
	25	calm, sunny	S.	11.10 a.m.	11.8
	27	sunny, warm	S.	12.15 p.m.	1.16
May	1	sunny, warm	E.	11.20 a.m.	5.5
	3	calm, misty	S.	12 noon	6.21
	5	showery, gusty	E.	11 a.m.	7.25
	9	showery, gusty	S.W.	11.50 a.m.	9.43
	12	rain, smooth	S.	12.45 p.m.	0.29
	15	rather rough, dull	W.	11.20 a.m.	3.40
	17	showery, dull	—	11.25 a.m.	5.15
	19	fine, warm	E.	0.15 p.m.	6.48
	22	fine, breezy	N.W.	10.25 a.m.	9.8
	24	fine, cloudy	S.	11.40 a.m.	11.4
	26	fine	S.W.	11 a.m.	0.44
	29	fine, warm	S.	10.40 a.m.	3.49
	31	fine, warm	S.	10.40 a.m.	5.20
June	2	fine, warm	N.W.	11.40 a.m.	6.35
	6	cold, rough	W.toN.W.	10.48 a.m.	8.46
	8	fine, cold	S.	11.20 a.m.	10.8
	12	cold, dull	W.	10.25 a.m.	1.49
	14	cold, dull	N.	10.25 a.m.	3.55
	19	cold, fair	N.W.	10.45 a.m.	8.16

		Weather.	Wind.	Greenwich time.	Morning tide.
	21	dull, cold	S.	11 a.m.	9.50
	27	cold, fine	S.	11.45 a.m.	3.13
	29	stormy, showery	S.	10.40 a.m.	5.3
July	4 P		S.	10.30 a.m.	5.3
	7 P	heavy swell	S.S.W.	10.40 a.m.	9.38
	11 P	fair	S.W.	10.45 a.m.	noon
	13 P	heavy sea	S.W.	12 noon	3.28
	18 P	fine	N.	10.50 a.m.	8.5
	21 P	very fine	S.	3 p.m.	10.2
	25 P	very fine	S.W.	10.50 p.m.	1.13
	27	very fine	N.W.	11.15 a.m.	3.46
August	1	misty	S.E. & S.W.	1.30 p.m.	7.12
	3	very fine	S.	11.5 a.m.	8.9
	8*a*	fine	E.	11 a.m.	11.32
	10	very fine	W.	10.55 a.m.	1.40
	16	windy, rough	S.	11.35 a.m.	7.43
	18	fine	S.	11.15 a.m.	8.57
	22	fine	E.	11 a.m.	11.42
	28	fine	S.	11.40 a.m.	5.39
	31	misty, swell	S.	11.10 a.m.	7.17
September	4	showery	W.	10.20 a.m.	9.25
	6	very fine	S.	11 a.m.	11.11
	8	very fine	N.E.	10.40 a.m.	11.35
	11	showery, fine	N.W.	10.40 a.m.	5.8
	13	fine	W.	10.40 a.m.	6.38
	15	fine	W.	noon	7.49
	18	fine	N.W.	10.30 a.m.	9.24

[*a* These samples were taken at 4 and 6 fathoms.]

LITERATURE.

1911. Bygrave, W. "Report on the Plankton of the English Channel in 1906." M.B.A. Inter. Fish. Inv., Cd. 4641, 1906–8.

1899. Cleve, P. T. "Plankton Researches in 1897." Kong. Svensk. Vetensk. Akad. Handl., Bd. 32, No. 7.

1900. —— "The Plankton of the North Sea, English Channel and the Skaggerak in 1899." *Ibid.*, Bd. 32, No. 2.

1903*a*. Gough, L. "Plankton, English Channel, February, March, May, August and November, 1903 and 1904." Bull. d. Rés. acq. pend. l. c. pér. pub. p. l. Conseil Intern. p. l'Explor. de la Mer.

1905. GOUGH, L. "Report on the Plankton of the English Channel, in 1903." M.B.A. Intern. Fish. Inv , Cd. 2670, 1902–3.

1907. —— *Ibid.*, Cd. 3837, 1904–5.

1912*a*. GRAN, H. H. "Preservation of Samples and Quantitative Determination of the Plankton." Publication de Circonstance, No. 62.

1912*b*. —— "The Plankton Production of the North European Waters in the Spring of 1912." Bull. Planktonique.

1908–15. HERDMAN, W. A. and SCOTT, A. "An Intensive Study of the Marine Plankton around the South End of the Isle of Man," etc. Parts I–VIII, Rep. for 1907–14 of the Lancs. Sea Fish. Lab.

1915. LEEGAARD, C. "Untersuchungen über einige Planktonciliaten des Meeres." Nyt. Mag. f. Naturv., Bd. 53, hft. 1.

1908. LOHMANN, H. "Untersuchungen zur Feststelluug des Vollständigen Gehaltes des Meeres an Plankton." Wiss. Meeressunter, n.d.d. Komm. z. wiss. unters d. deutsch Meere in Kiel," Vol. X.

1908. OSTENFELD, C. H. "On the Immigration of *Biddulphia sinensis* Grev., etc." Meddel f. Komm. f. Havundersøgelser, Bd. I.

1913. —— "Phytoplankton og Protozoei." De Danske Farbandes Plankton, I, Aar. 1898–1901.

TABLE I

The Microplankton of Puget Sound from the region beyond the Breakwater, [illegible] the average number of individuals in 50 cc. for each week, also relative abundance in the tow-nettings. The numbers show the individuals in the water samples, the letters their relative abundance in the tow-nettings.

Month. / Week ends	1915 September 25	October 2	9	16	23	30	November 6	13	20	27	December 4	11	18	25	1916 January 1	8	15	22	29	February 5	12	19	26	March 4	11	18	25	April 1	8	15	22	29	May 6	13	20	27	June 3	10	17	24	July 1	8	15	22	29	August 5	12	19	26	September 2	9	16	23
																															None taken																						
1 Melosira [illegible]	rr					0·3					rr 0·2						r 0·2		0·2 r	r	r		0·2 r	0·2 r	0·3 rr	c	0·3 rr	rr												rr												r	
2 [illegible]	22 c	32	7 rr	28	28 r	2 r	91	22	85	14	53 +	63 +	62 +	28 +	78 +	121 +	81 +	80 r	67 r	26 r	49 +	62 r	53 r	14 r	8 rr	12	11 r	35 r	20 rr	7		23	9 rr	8	3 rr	2	3 rr	5 rr	2	3		7 rr	2 rr	2		3 r	4	24 rr	rr	19 rr	4 rr	17 rr	11
3 [illegible]	24	129 c	850 cc	108	293 cc	2	41 cc	19 r	19 cc	11 cc	15 cc	2 +	6 +	2 +	rr	0·7	8	35	17 c	17 cc	16 cc	13 +	40 cc	15 cc	30 r	53 c	29 c	58 cc	31 +	194 cc		4318 cc	191 c	84 +	79 +	156 r	122 cc	5	2	0·7	12	6 rr	1 rr	3 rr	8 rr	26 rr	108 cc	341 cc	362 cc	2042 cc	74 cc	[illegible]	[illegible]

TABLE I—*continued.*

The Microplankton of Plymouth Sound from the region of the Breakwater, showing the average number of individuals in 50 cc. for each week, also relative abundance in the tow-nettings. The numbers show the individuals in the water samples, the letters their relative abundance in the tow-nettings.

Month.	1915. September.	October.					November.				December.				1916. January.					February.				March.				April.					May.				June.				July.					August.				September.			
Week ending	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23
61. Acnanthes longipes Ag.		r			0·2																		r						rr																								
62. Navicula membranacea Cleve	0·1		0·3 r	12 c	3	5	12	21	1 r	2 rr																						2			[illegible]			2		0·1 r	4	c	10	r		rr	[illegible]				2 r	1 r	2
63. ,, sp.	2 r	2 rr	1 +	4	4 rr	4 r	3 r	2	2 r	2 r	2 rr	2	2 r	0·5 r	0·3	0·3 r	1	1	1	1 r	0·5	2	2		r		rr	rr	r				0·2	1	2	1	0·1	2	0·5	0·7	1	0·8	0·7	[illegible]		1	1		0·7		4 rr	4 rr	1
64. Pleurosigma sp.	1 r	1 rr	0·3 r	2 r	2 rr	2 rr	2 rr	1	4 r	2 r	5 rr	3 r	2	0·8	3	3	3 r	4	2	0·5	3	3	2	0·8 rr	2	0·7 r	2	2 r	2 r	3 rr		2 rr	rr	0·5	1 r	0·4 rr	0·3	0·5	0·2 r	1 rr	0·8		r	0·7 r	0·2 rr	rr	0·3	2		1	0·7	[illegible]	2
65. Mastogloia sp.	0·4	0·4		10	2003 rr	348	1650	70				rr																					0·7	130	112	578	166	71	173	150			20	67	162	1133		25					
66. Amphiprora maxima Greg.	0·1	0·1								0·1 rr		rr		rr	0·3	0·1 rr	0·2		0·1									0·1	0·3			0·2		rr	rr									r		0·2	rr	rr					
67. Amphora ostracaria Bréb.				rr																																																	
68. ,, sp.	rr	rr			0·2				rr		rr																						0·1										0·2 r			0·2	0·2 r	r		rr			
69. Nitzschia closterium W. Sm.	1	0·7	0·7	49	129	5	5	2	2 rr	1	2	1	2	0·5			0·2		2	0·3	0·3	0·3	0·2		0·7	0·8	0·8	1	1	3		5 rr	3 r	6	3	2 rr	0·7	6	0·3		0·8	0·2	0·7 rr	0·7	10 rr	2	3	3	[illegible] r	7 r	[illegible] rr	5 rr	[illegible]
70. ,, seriata Cleve	0·1 r			0·2	1		0·3	0·5	0·2 rr																0·2							0·2									0·8 rr	2	0·2		15 cc	4	6	6	21 rr	0·3	2		
71. ,, delicatissima Grev.											r		rr																			rr	167 cc	2367 cc	906 cc	179 cc	28 cc	210 cc	5 cc	2	1	3	3	2	22	0·3	15 r	4	24 r	5 rr	[illegible] r	16	16
72. ,, panduriformis Gm.	0·1			0·2	0·1	4			rr						0·3	0·1				0·2																																	
73. Bacillaria paradoxa Gm.	1 c	3 r		2 +		r	r	r	r	2 r	4 +	r	1 r	4 +		r	3 r	r	7 c	+	+	r	0·5 +	r	2		2	2	1 c	c					1				1	r		rr			1			2 r			0·4	1	r
74. Campylodiscus and Surirella spp.	rr	0·2 rr	r	r	r	0·2 rr	0·5 r	r	rr	rr	0·2 rr	r		r		0·1 rr		rr	rr		r						rr									rr		0·1 rr		r		0·2 r		0·2 r						0·2	r	rr	
Peridiniales																																																					
75. Exuviella compressa (Bailey)	0·2	0·1		0·2																																						0·7			0·5								
76. Prorocentrum micans Ehr.	5 +	4 r	0·6 rr	6 +	4	2	2	0·2	0·3		0·2	0·3		0·2			rr	0·3						0·2	0·2		0·8	0·1	0·7	0·3 rr		0·2	0·3	0·3	0·5	1	1 r	2	0·5		2	0·3 rr	0·8 rr	0·7	3 rr	7 rr	10 rr	17 rr	19 rr	17 r	14 r	21 r	12 r
77. Dinophysis acuta Ehr.																								rr													rr			0·2 r		rr	0·2 +		0·2 +	3 +	0·3 rr						
78. ,, acuminata Cl. & L.																																					0·5	3	6	2	0·5				0·3	0·8	1	0·3		0·5		0·9	3
79. ,, homunculus v. tripos Lemm.																																																rr					
80. ,, ovum Schutt					0·2																												0·4		0·1	0·7		1	0·3 rr		0·2		0·2				0·5		rr		rr		
81. ,, rotundatum Cl. & L.	r	0·1	0·2	0·1	0·2																																	0·4	0·2	0·8 rr	0·8	0·2	0·2 rr		0·7	0·2 rr	0·3 rr	r	0·6	0·5	0·1		
82. Glenodinium bipes Pauls.											0·2								0·1													0·2	0·7	2	0·3	1	3 rr	38	12	0·5	0·5					0·2			0·3				
83. Protoceratium reticulatum Cl. & L.																																						0·7	0·3	0·5	rr					0·2			0·3				
84. Gonyaulax triacantha Jörg.																																						0·2	0·2		0·2			0·2		0·8	4						
85. ,, polygramma Stein				0·3																																									0·2		0·3						
86. ,, spinifera (Cl. & L.)																				0·2															0·1					0·5	1					0·5							
87. ,, scrippsæ Kofoid																																			0·1	0·1				0·2				0·5	1	0·3	0·3		3	0·2	0·8		
88. ,, polyedra Stein													rr																rr						0·6				0·7							0·3							
89. Amylax lata Meunier	0·1			0·1																																		0·2								0·2						0·1	0·6
90. Diplopsalis lenticula Bergh	r	r		r		r	r	r	rr	r																												0·2								0·2				0·3	0·1		
91. ,, pillula Ostf.																																						7	2	0·7	1												
92. Peridinium orbiculare Paul.													r	0·2 rr																																							
93. ,, cerasus Pauls.																													0·5 rr	0·3		0·3 rr	1 rr	0·3		0·1	0·3	1	2	2	3 rr		0·2		0·2	0·5 rr	1	0·3		0·2	0·1	0·5	
94. ,, roseum Pauls.																																								0·3	1									0·2			
95. ,, ovatum (Pouchet)																												r	0·7 +	rr		rr	+	rr	r			rr		0·2 r	0·5 rr			r		0·2 r	0·2 r	0·2 +	r	0·2 r	0·4 r	0·4 c	r
96. ,, pedunculatum Schutt													rr			rr			rr																	0·1	r																
97. ,, pallidum Ostf.		0·1											rr																							0·1					0·2		0·3 rr			1 r		+	r		0·1		
98. ,, pellucidum (Bergh.)																								r	rr		rr	0·1	1 +				0·6 +	1	0·4 r		0·1 rr	0·7 +	0·5	1 r	0·2	0·2 rr	0·2	0·2	0·5	1 r	0·7 r		0·3	0·5		0·1	
99. ,, oceanicum Vanh.																	rr		rr	rr																								r		rr							
100. ,, divergens Ehr.	0·1 r	0·1 r	r	0·1 c	+	0·3 +	r	+		r														rr	rr								r		rr		c	0·2	0·2	0·2 rr	rr	r	r	r		r	0·2		rr	rr	rr	cc	
101. ,, crassipes Kofoid																		r																														+			r		
102. ,, conicum (Gran.)	0·3 r	0·1 r	3	0·1 r	0·2 rr	0·3	0·1 r	0·2	r	rr			r	r						0·5 rr				+	rr	0·3 r	+	0·2 r				rr	0·5 cc	0·7 rr	0·1	r	0·7	0·2	4	0·4 r	0·7 r	rr			rr		0·8 r	0·2 rr	+	0·2	0·7 r	0·1	
103. ,, Thorianum Pauls.																							r																		rr				rr								
104. Peridiniaceæ juv. et indet.																										0·2												2	1	4	2			0·2	5	77 r	11	2	2	2	3	5	3
105. Pyrophacus horologicum Stein																																															r				rr	rr	
106. Oxytoxum Milneri Murr. & Whitt.																																															0·2						
107. Ceratium platycorne v. Daday				r				rr		+	r	r	r	rr																																							
108. ,, bucephalum (Cleve)	r	r	r	0·1 cc	0·8 +	c	0·1 +	0·2 +	+	+																														r			r	rr		0·2	r	0·2 +	r	0·8 r	r	0·1 r	
109. ,, tripos (O. F. Mull.)													rr																												0·7								rr			0·1 r	
110. ,, tripos f. lineata (Ehr.)											rr																												0·5			0·2	rr									0·2	2
111. ,, arcticum (Ehr.)												r																																		0·3				0·3		rr	
112. ,, macroceras (Ehr.)	0·1			rr		rr	rr	r		rr	rr		r						rr		rr		rr																							rr				0·2		0·1 rr	
113. ,, furca (Ehr.)				r	rr	rr																							rr									0·2														0·1 rr	
114. ,, fusus (Ehr.)	0·5 c	0·2 r	rr	+	0·7			r		0·1	1			0·2					0·1				0·2			rr	r	r	r	r			0·3 r		+	0·3 rr	c	r	0·3 +	0·3 +	0·2 +	0·8 +	1 cc	0·3 r	0·2 rr	0·3 cc	2 r	1 +	3 c	1	0·5 rr	1	
115. Amphidinium crassum Lohm.																																						0·2	0·2	0·3	2				0·3	0·2				0·3		0·2	
116. Gymnodinium teredo Pouchet	0·2		0·2			0·7 rr	0·6		0·3			c	r	r										0·2	0·2								0·1			rr	0·1	0·7	0·3			rr			1					0·3			
117. ,, pseudonoctiluca Pouchet																																					0·2				0·2												
118. ,, viridis n.sp.																																								0·2													
119. ,, rhomboides Schutt							0·1																				0·1								0·4 rr	0·1	0·7	7	7	1	1				1	1	2	0·7	1	0·3	0·2		
120. ,, triangularis n.sp.																																						0·5															

TABLE I—*continued.*

The Microplankton of Plymouth Sound from the region inside the Breakwater, showing the average number of individuals in 50 cc for each week, also relative abundance in the tow-nettings. The number gives the individuals in the water samples, the letters the relative [illegible]

Month	1915. September	October					November				December				1916. January					February				March				April					May				June				July					Aug.				Sept.			
Week ending	25	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9	16	23
121. Gymnodinium minor n.sp.																																							0·5		0·2					0·2							
122. Spirodinium fissum Levander																																						8								0·2		0·3				0·2	
123. ,, spirale (Bergh.)				0·1			0·2				0·2	r	r	0·2					0·1				r				0·1							1	0·5 rr	0·4	0·3	2	4	0·8	0·3				1	0·3	2	0·3	0·3	0·3	0·2	0·7	
124. ,, crassum Pouchet																																								0·3					0·2								
125. ,, glaucum n.sp.																																		0·2		0·6 rr	0·1	12	21	1	1	0·2				0·5	0·7	0·7	2	0·7	0·1	1	2
126. Cochlodinium helix (Pouchet)																																															0·3						
127. ,, pellucidum Lohm.																																																					
128. Pouchetia armata Dogiel																																	0·2																				
129. ,, parva Lohm.																																													0·2			0·2		0·3		0·1	
130. ,, fusus Schütt																																																					
131. Polykrikos Schwarzii Butsch.		0·1																																									rr									0·2 r	
132. Gymnodiniaceæ juv. et indet.																									0·2							0·8	0·5	1	1	0·5	1	0	5	1	1		0·2 r		0·2	1	r	0·2	0·3	0·7 rr		0·5	
133. Pyrocystis lunula Schütt				rr																																			0·3	rr		0·2	0·2 rr	0·2									
134. Oxyrrhis marina Duj.																																						rr															
Flagellatæ.																																																					
135. Phæocystis Pouchetii (Hériot)																																	19	70	12	8	4	11	0·2						1								
136. Dinobryon sp.																																													3	0·7							
137. Carteria sp.																																								0·3	0·3				1								
138. Trochiscia Clevei Lemm.				0·1																													0·1																				
139. Halosphæra viridis Schmitz		0·1	0·2	0·1	0·2		0·1				0·3																					0·2								0·2	0·2			0·5	0·2	0·2	0·2	0·2					
140. Flagellata indet.	0·1																															0·3				0·1	0·1				0·3			0·3	1	0·7	0·2	0·7			1	0·5	0·6
Coccosphærales.																																																					
141. Pontosphæra Huxleyi Lohm.	0·2	0·2			0·3																																														0·1		
Silicoflagellata.																																																					
142. Dictyocha fibula Ehr.				0·2				0·2		0·1			0·3				0·2		0·1							0·2	0·2	0·2					0·1		0·1	0·1	0·1	0·2		0·3					0·2					0·5	1	1	0·3
143. Distephanus speculum (Ehr.)	0·1	0·2	0·3	1	1	0·3	0·4	0·2	0·2				0·1											0·2	0·2	0·5	0·2	0·2	0·5	1		0·7																	0·6	1	0·3		
Gymnomyxa.																																																					
144. Amœba sp.			0·2			0·2		0·3																										0·2	1	4	0·5	0·2	1	0·7						0·3	0·2				0·6	0·1	
145. Foraminifera indet.	r	0·1 r	0·2 r	0·2 c	0·5 r	0·3 r	0·1 rr	0·2 r	+	0·2 r	0·2 rr	0·6 +	0·8		rr	0·4 +	0·3	0·3	1 r	1 r	0·7 r	2 r	1	0·5 r			0·2 r	0·2						0·2														r			0·4	rr	
146. Heliozoa indet.										rr																																							0·3				
147. Acanthochiasma fusiforme Haeckel		0·1 rr		0·2	0·3	2	1	0·7								rr							+		rr		rr														0·2				0·2 rr	0·2	0·2	rr		0·3			
148. Lithomelissa setosa Jörg.									rr	rr				rr														rr						rr																			
149. Amphimelissa setosa Cleve						0·2	0·1			r																							0·1																				
Suctoria.																																																					
150. Paracineta limbata Maup.								0·2																																													
151. Acineta tuberosa Ehr. v. Fraiponti Fr.			rr		0·2																																																
Infusoria.																																																					
152. Lachrymaria sp.																																		0·2																			
153. Coleps sp.				0·1																																											0·2 r	rr			0·1		
154. Tiarina fusus Cl. & L.																																								0·2			0·2			0·5	3 rr	0·7 +		0·8	0·3 rr	1	
155. Mesodinium sp.																			0·1	0·2			0·2		0·3	0·7	0·3			2		0·7	0·1	1	1		0·1	0·2							0·2		0·2	0·2		0·2	1	1	
156. Nassula sp.																																		0·2							0·2					0·2	0·5		0·3				
157. Strombidium caudatum From.		0·1					0·2																																							0·2							
158. Laboea conica Lohm.	0·8		0·1				0·1						0·2						0·1	1	0·2				0·5	0·5	0·2						0·3	0·5	0·1	0·3	0·2	1		1	0·2	0·2		0·5	0·7	0·5	0·2	0·3				0·5	
159. ,, strobila Lohm.	0·4	0·2					0·1																																	0·3	rr	1 r	0·3								0·1		
160. ,, acuminata Leegaard	0·1			0·1																				0·2													0·1	0·2							0·2	0·2					0·1	0·3	
161. ,, spiralis Leegaard							0·1		0·1																									0·2	0·1								1	0·8							0·2	0·1	
162. ,, sp.	2	1	2	0·4	0·5		0·8	0·2	0·6	0·5			0·3											0·3		0·3 rr	0·2	0·2	0·2			0·2	0·2	1 r	0·4 r	0·1 r		0·7	0·5	r	0·7	0·7	0·2	0·5	0·7 r		0·3	0·7	2				
163. Lohmaniella oviformis Leegaard																																														0·2							
164. Euplotes vannus O.F.M.									0·1																																												
165. ,, sp.																									0·2							0·5				0·2																	
166. Tintinnus subulatus Ehr.	0·1			r	0·2		rr		rr																															0·3			r	0·7		0·3	11 rr	1	1 rr	1 rr	0·3	0·7	0·3
167. Tintinnopsis beroidea (Stein)						0·5 r	5 cc	0·2 rr	0·5 cc	0·3 rr	1 cc	0·3	2 cc	6 c	rr	0·4 +	2 +	4 +	0·5 +	2 +	0·2 rr	0·3	0·5	r		0·3 rr	0·3 r	2 cc	1 r	0·6 r		0·2 r	rr								0·2 r	0·5	1	1	2 cc	2 cc	6 r	3 r	5 +	0·7 r	3 +	1 rr	0·6 rr
168. ,, campanula (Ehr.)	+	0·2 r	r	r					0·2	rr						rr																														0·3 rr	rr	0·3 r	0·6	rr	0·1 rr	0·1 r	
169. ,, ventricosa Cl. & L.	3 +	0·9 +	2 +	0·7 +	1 rr		rr		rr		0·3	0·6	rr		0·3				0·1		rr	0·3	0·2		r				0·3 +				0·8 r		0·8	1	4 r	1	3	1 rr	1	0·3	0·7	4 rr	2	0·3	0·3	0·3	3	1 rr	1 r	0·6 r	r
170. Cittarocyclis denticulata Ehr.		r	+				0·1									0·2																																			0·3	rr	
171. ,, edentata Brandt																																																					
172. Infusoria indet.			1	0·							0·2			0·3				0·3	0·1				0·2		0·3 r					0·3		0·5		3	0·9	1		0·2							2	0·2	0·3			1	3	3 r	1

TABLE II

Average number of Diatoms and Peridiniales in 1 cc. *for each month.*

	Diatoms. In 50 cc. Surface.	Diatoms. 5 fath.	Diatoms. 7 fath.	Diatoms. Total in 150 cc.	Diatoms. Average in 1 cc.	Average in 1 cc. for month.	Peridiniales. Surface.	Peridiniales. fath. 5	Peridiniales. 7 fath.	Peridiniales. Total in 150 cc.	Peridiniales. Average in 1 cc.	Average in 1 cc. for month.
1915. September 21	82	61	55	198	1·32		8	15	14	37	0·24	
„ 23	113	104	76	293	1·95		5	8	1	14	0·09	
„ 25	191	104	77	372	2·48	2·99	6	7	7	20	0·13	0·12
„ 27	355	84	191	630	4·28		8	2	7	17	0·11	
„ 29	334	233	184	751	5·01		8	9	3	20	0·13	
October 1	321	247	282	850	5·66		1		1	2	0·01	
„ 4	901	1895	944	3740	24·93		3	2		5	0·03	
„ 6	868	402	505	1775	11·83			2	2	4	0·02	
„ 11	143	166	451	760	5·06		8	9	6	23	0·15	
„ 13	468	150	62	680	4·53		13	12	8	33	0·22	
„ 15	358	168	70	596	3·97	17·41	5	3	5	13	0·09	0·08
„ 18	13213	225	119	13575	90·50		7	11	3	21	0·14	
„ 21	403	235	845	1483	9·88		9	6	2	17	0·11	
„ 27	995	60	27	1082	7·21		5	5	2	12	0·08	
„ 29	1143	362	74	1579	10·53		4	1	2	7	0·04	
November 1	3469	522	73	4064	27·09		6	1	2	9	0·06	
„ 3	3647	48	52	3747	24·98		11	5	2	18	0·12	
„ 5	6114	197	185	6496	43·36		3		2	5	0·03	
„ 8	535	53	79	667	4·44			2		2	0·01	
„ 11	68	62	87	217	1·44			1		1	0·006	
„ 15	168	101	213	482	3·21	9·5	1		1	2	0·01	0·02
„ 17	50	158	86	294	1·96		3			3	0·02	
„ 19	52	99	189	340	2.26				2	2	0·01	
„ 22	102	35	70	207	1·38							
„ 24	81	64	123	268	1·78							
„ 26	114	68	29	211	1·40				1	1	0·006	
„ 29	90	104	69	263	1·75		1	1	1	3	0·02	
December 2	131	71	78	280	1·86		5	1		6	0·04	
„ 9	72	99	95	266	1·77		1			1	0·006	
„ 13	65	74	83	222	1·48							
„ 16	59	103	154	316	2·10	1·5						0·008
„ 20	52	77	60	189	1·26		1	1		2	0·01	
„ 22	16	23	24	63	0·42			1		1	0·006	
„ 29	41	137	101	279	1·86							
1916 January 3	59	184	119	362	2·41							
„ 5	47	118	422	587	3·91							
„ 8	53	99	92	244	1·62							
„ 11	109	85	144	338	2·25							

TABLE II—*continued.*

Average number of Diatoms and Peridiniales in 1 cc. *for each month.*

	Diatoms. In 50 cc. Surface.	Diatoms. 5 fath.	Diatoms. 7 fath.	Diatoms. Total in 150 cc.	Diatoms. Average in 1 cc.	Average in 1 cc. for month.	Peridiniales. Surface.	Peridiniales. 5 fath.	Peridiniales. 7 fath.	Peridiniales. Total in 150 cc.	Peridiniales. Average in 1 cc.	Average in 1 cc. for month.
1916. January 14	139	52	116	307	2·04							
„ 18	104	171	115	390	2·60	2·19	1			1	0·006	0·003
„ 24	122	132	77	331	2·20							
„ 26	105	97	78	280	1·86			2		2	0·01	
„ 28	89	94	136	319	2·12							
„ 31	20	34	139	139	0·92		3	1		4	0·02	
February 5	90	47	23	160	1·06							
„ 8	127	128	126	381	2·54							
„ 10	34	44	11	89	0·59			1		1	0·006	0·002
„ 17	83	71	129	283	1·88	1·62						
„ 21	110	74	101	285	1·90							
„ 25	160	43	145	348	2·32		1			1	0·006	
„ 28	81	34	45	160	1·06		1			1	0·006	
March 1	57	38	4	99	0·66		1			1	0·006	
„ 8	147	57	145	349	2·32							
„ 10	83	40	54	117	1·18		1		2	3	0·02	
„ 14	81	59	20	160	1·06		2			2	0·01	
„ 16	273	48	19	340	2·26	2·07	1			1	0·006	
„ 21	49	143	58	250	1·66			2		2	0·01	0·02
„ 23	120	151	98	369	2·46			2	1	3	0·02	
„ 27	275	51	70	396	2·64		14	1	1	16	0·10	
„ 29	195	171	129	495	3·30		1	3	1	5	0·03	
„ 31	153	127	207	487	3·24		1			1	0·006	
April 4	53	120	100	273	1·82		1	6	2	9	0·06	
„ 6	46	106	113	265	1·76		1	4	3	8	0·05	
„ 10	712	85	74	871	5.80	38·56			2	2	0·01	0·03
„ 25	2340	1517	2972	6829	45·52		3	1		4	0·02	
„ 27	12,680	4705	3303	20,688	137·92		3	1	1	5	0·03	
May 1	1909	1142	1368	4419	29·46		9	1	5	15	0·10	
„ 3	1498	641	262	2401	16·00		13	5	4	22	0·14	
„ 5	415	229	415	1059	7·06		1	7	4	12	0·08	
„ 9	3331	1466	4592	9389	62·59		4	19	6	29	0·19	
„ 12	1911	2354	3141	7406	49·37		12	2	1	15	0·10	
„ 15	510	832	537	1879	12·52	30·42	6	12	8	26	0·17	0·12
„ 17	1751	3281	1442	6474	43·16		1	6	5	12	0·08	
„ 19	1271	1034	381	2694	17·96			4		4	0·02	
„ 22	997	1502	1429	3928	26·18		13	15	7	35	0·23	
„ 24	6451	213	93	6757	45·04		1	16	10	27	0·18	

TABLE II—*continued.*

Average number of Diatoms and Peridiniales in 1 cc. *for each month.*

	Diatoms. In 50 cc. Surface.	Diatoms. 5 fath.	Diatoms. 7 fath.	Diatoms. Total in 150 cc.	Diatoms. Average in 1 cc.	Average in 1 cc. for month.	Peridiniales. Surface.	Peridiniales. 5 fath.	Peridiniales. 7 fath.	Peridiniales. Total in 150 cc.	Peridiniales. Average in 1 cc.	Average in 1 cc. for month.
1916. May 26	1160	125	88	1373	9·15		1			1	0·006	
„ 29	4628	366	1377	6371	42·47							
„ 31	3468	1412	308	5188	34·58		14	10	19	43	0·28	
June 2	2017	296	173	2486	16·57		5	20	4	29	0·19	
„ 6	1719	703	468	2890	19·26		107	62	55	224	1·89	
„ 8	557	671	606	1834	12·22		223	70	74	367	2·44	
„ 12	1052	205	107	1364	9·09		56	97	124	277	1·84	1·02
„ 14	357	99	155	611	4·07	9·12	93	67	38	198	1·32	
„ 19	879	306	149	1334	8·89		21	35	24	80	0·53	
„ 21	181	156	82	419	2·79		53	13	15	81	0·54	
„ 27	326	205	119	650	4·33		24	8	13	45	0·30	
„ 29	266	189	271	726	4·84		47	27	6	80	0·53	
July 4	71	176	116	363	2·42			6	2	8	0·05	
„ 7	73	10,155	83	10,311	68·74		1	8	2	11	0·07	
„ 11	253	200	180	633	4·22		4	2	6	12	0·08	
„ 13	100	347	136	583	3·88	21·39	8	2		10	0·06	
„ 18	292	504	337	1133	7·55		2	5		7	0·04	0·12
„ 21	824	227	169	1220	8·13		1	5	1	7	0·04	
„ 25	2521	125	764	3410	22·73		12	35	6	53	0·35	
„ 27	1164	5421	1434	8019	53·46		7	20	22	49	0·32	
August 1	4588	987	7833	13,410	89·40		87	103	182	272	1·81	
„ 3	746	1655	1002	3403	22·68		39	63	11	113	0·75	
„ 8	655	586	894	2135	14·23		38	17	55	110	0·73	
„ 10	1702	821	3389	5912	39·41		26	46	42	114	0·76	
„ 16	1043	523	1193	2759	18·39	31·78	25	42	20	87	0·58	
„ 18	142	263	62	467	3·11		15	14	6	35	0·23	
„ 22	1136	432	292	1860	12·40		58	39	5	102	0·68	0·73
„ 28	7276	1743	1439	10,458	69·72		43	22	12	77	0·50	
„ 31	360	2041	103	2504	16·69		50	35	6	91	0·60	
September 4	416	30	129	575	3·83		23	12	2	37	0·24	
„ 6	863	490	352	1705	11·36		16	38	10	64	0·42	
„ 8	1363	1508	2397	5268	35·12	17·11	32	82	53	167	1·11	
„ 11	3505	1278	1020	5803	38·68		59	87	16	152	1·01	0·64
„ 13	271	843	103	1217	8·11		51	39	9	99	0·66	
„ 15	292	243	300	835	5·56		40	33	19	92	0·60	
„ 18							26	23	lost.	49	0·19	

The Peridiniales of Plymouth Sound from the Region beyond the Breakwater.

By

Marie V. Lebour, M.Sc.,

Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist at the Plymouth Laboratory.

With Figures 1–14 in the text.

THE following list includes all the Peridiniales identified in the plankton throughout the year from September, 1915, to September, 1916, from the water samples, details of which will be found in another paper in the same journal (p. 133). Also from the plankton in the tow nets in the same year and a portion of the summer 1915. As is shown in the above-mentioned paper, the summer is the time for nearly all the Peridiniales, June being the maximum month. After October very few are seen in the water samples, although in the tow nettings the larger and stronger forms, such as *Ceratium* and *Peridinium*, are still present.

The new and least-known forms belong to the *Gymnodiniaceæ*, which have no cellulose sheath. Perfectly transparent and extremely thin cases, however, are often seen which may be close fitting or many times larger than the gymnodinian. *Pouchetia* and various species of *Cochlodinium* are instances of this (see Plate II, Fig. 14). The *Gymnodiniaceæ* are perhaps the most interesting of the Peridiniales, as many of them obtain nourishment holozoically and often the food can be determined. Throughout June the flagellate *Phæocystis pouchetii* was excessively abundant, and this furnished food for many gymnodinians (e.g. *Gymnodinium rhomboides* and *G. triangularis*, see Plate I, Figs. 6 and 7).

Division stages in this group are often seen which in the genera *Gymnodinium* and *Spirodinium* take place usually, if not always, in the free state and not in capsules as in *Pouchetia* and others (Pouchet, 1885; Dogiel, 1906).

Although no special investigation has been made closer inshore, the examination of a few samples of water show that many of the species occur near the land, such as *Gymnodinium* and *Spirodinium* species and *Dinophysis*, besides several species of *Peridinium*.

In the following list 60 species are recorded. Of these 5 of *Gymnodinium*, 2 of *Spirodinium*, and one of *Cochlodinium* are new. Twenty-one species are, I believe, new records for British seas and 28 are new records for the Plymouth area. In addition to those recorded and described there are many which I have not been able to identify. Some of these are young forms, others collapsed before they could be properly observed, and others were distorted. Among these there are probably many new species belonging to the *Gymnodiniaceæ*.

The classification adopted is that of Paulsen (1908) in "Nordisches Plankton." Those marked * are new to Plymouth, those marked N.R. are new records for British seas.

PROROCENTRACEÆ.

Genus Exuviella Cienk.

(1) * *Exuviella compressa* (Bailey) Ostenfeld. Occasionally in water samples in the summer.

Genus Prorocentrum Ehrenberg.

(2) *Prorocentrum micans* Ehrenberg. From May to October in the water samples, rarely in tow nettings. Commonest in the late summer. Its maximum early in September.

PERIDINIACEÆ.

Genus Dinophysis Ehrenberg.

(3) *Dinophysis acuta* Ehrenberg. Fairly frequent in very fine tow nettings, not so common in the water samples. May to October.

(4) *D. acuminata* Cl. and L. Common in water samples, usually gets through the very fine net. There is a small form of this species which occurs more rarely than the type in the spring and early summer.

(5) *D. ovum* Schütt. Occasionally in water samples.

(6) *D. rotundatum* Cl. and L. Common in water samples.

(7) *D. homunculus* Stein v. *tripos* Gourr. Occurred once only in tow nettings, August, 1916.

Genus Glenodinium (Ehrenberg) Stein.

(8) * *Glenodinium bipes* Pauls. Common from May to September. Abundant in May and June with its maximum in early June. This species is so small that it always gets through the very fine

net. It is exceedingly active and lives many hours in a bottle of sea-water.

Genus PROTOCERATIUM Bergh.

(9) * *Protoceratium reticulatum* (Cl. and L.). Occurs fairly commonly in water samples from May to September, commonest in August.

Genus GONIAULAX Diesing.

(10) * *Goniaulax triacantha* Jörgensen. Rare, in water samples, May to September.

(11) *G. polygramma* Stein. Rare, in water samples, May to September.

(12) *G. spinifera* (Cl. and L.). This is the commonest species of *Goniaulax*. May to September.

(13) N.R. *G. scrippsæ* Kofoid. Occasionally in the water samples, July to September.

(14) *G. polyedra* Stein. Occasionally in water samples, May to September.

Genus AMYLAX Meunier.

(15) N.R. *Amylax lata* Meunier. Occurred a few times singly. Slightly smaller than the type.

Genus DIPLOPSALIS Bergh.

(16) *Diplopsalis lenticula* Bergh. Fairly common in very fine tow nettings and in water samples. May to September.

(17) N.R. *D. pillula* Ostf. This minute species is abundant in June in the water samples, very often with *Glenodinium bipes*.

Genus PERIDINIUM Ehrenberg.

Sub-genus PROTOPERIDINIUM Bergh.

(18) *Peridinium orbiculare* Paulsen. Occurs rarely in the water samples.

(19) * *P. cerasus* Paulsen. This little species is one of the commonest and easily recognised. Occurs fairly frequently but never in large quantities in the water samples.

(20) * *P. roseum* Paulsen. Very like the last species but larger and flatter. Occurs rarely in the water samples.

(21) *P. ovatum* (Pouchet). Common in late summer but rare in May and June. Specimens with broad and conspicuously striated interspaces between the plates are as common as the typical forms and are probably older, as Mangin (1913) has already noted. More common in tow nettings than in water samples.

(22) *P. pedunculatum* Schütt. Very rare, in water samples only.

(23) *P. pallidum* Ostf. This and the following species are both common, the present species being larger is commoner in the tow nettings.

(24) *P. pellucidum* (Bergh). Common in water samples.

Sub-genus EUPERIDINIUM Gran.

(25) *P. oceanicum* Vanh. Rare in tow nettings.

(26) *P. divergens* Ehrl. Abundant in the tow nettings, especially in August and early September. Following Meunier (1910) I have reunited the *P. depressum* of the "Nordisches Plankton" with this species.

(27) *P. crassipes* Kofoid. Not very common in the tow nettings in August and September.

(28) *P. conicum* (Gran). This species and *P. divergens* are almost the only peridinians to be found in winter: although not abundant *P. conicum* is found throughout the year both in tow nettings and water samples. Commonest in early spring.

(29) N.R. *P. Thorianum* Paulsen. Rare in water samples in June. Meunier (1910) gives good figures of this species, which resemble the Plymouth form more than do Paulsen's. The present specimens have small knobs conspicuously ornamenting the skeleton which are very characteristic.

Genus PYROPHACUS.

(30) N.R. *Pyrophacus horologicum* Stein. Occurred very rarely in tow nettings in August.

Genus OXYTOXUM Stein.

(31) N.R. *Oxytoxum Milneri* Murr. and Whitt. I have referred to this species, a very small Oxytoxum about half the size of the type but agreeing with it in form. Only one specimen was found in August in the water samples.

Genus CERATIUM Schrank.

(32) N.R. *Ceratium platycorne* V. Duday. Rare, occurred singly two or three times in the tow nettings.

(33) *C. bucephalum* (Cleve). Occurred sparingly in tow nettings in early summer, more frequently in the late summer months.

(34) *C. tripos* (O. F. Müll.). Occasionally in water samples and tow nettings. A variety which approaches the form *lineata* (Ehrb.) and which I have referred to this variety occurs more frequently (Fig. 1). This has a short and straight apical horn, the hind horn nearly straight and the right horn about one-third as long as the left. The usual markings are longitudinal striations from the apex to the girdle, sometimes also with reticulations.

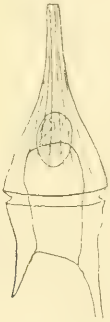


FIG. 1.—*Ceratium tripos* (O. F. Müll.) f. *lineata* (Ehrb.). × 466.

Although apparently nearest to the form *lineata*, the apical horn is very much shorter—less than half the length from its apex to the girdle.

(35) * *C. arcticum* (Ehrb.). Very rare, in tow nettings, 1915.

(36) *C. macroceras* (Ehrb.) Cleve. Rare in tow nettings.

(37) *C. furca* (Ehrb.). Occasionally, in tow nettings and water samples in summer.

(38) *C. fusus* (Ehrb.). The commonest *Ceratium* here. Occurs both in tow nettings and water samples and is often the only peridinian present in the winter. Maximum in October.

GYMNODINIACEÆ.

By far the greater portion of the Peridiniales of this area belong to this group and are missed almost entirely by the tow nets, only a few of the larger forms being retained by them.

Genus AMPHIDINIUM Cl. and L.

(39) N.R. *Amphidinium crassum* Lohmann. I have referred to this species, a form between *A. crassum* and *A. longum* of Lohmann, but which is slightly larger than either of these (Fig. 2). The shape of the body is not so pointed posteriorly as in *A. longum* but not so broadly rounded as in *A. crassum*, the greatest breadth being in about the centre of the body. The nucleus is posterior as in both forms, and a coloured body, greenish, is situated just in front of the nucleus and behind the transverse groove, with small refractive bodies scattered round it. This is perhaps the remains of ingested food material. A thin transparent covering can sometimes be seen detaching itself from the body. Length of body 0·030 mm. The only record so far of this species is by Lohmann from Kiel.

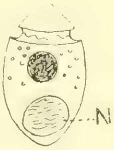


FIG. 2.—*Amphidinium crassum* Lohmann. × 466. N=nucleus.

Genus GYMNODINIUM Stein.

(40) N.R. *Gymnodinium teredo* Pouchet. Fairly common in July and August in the water samples in 1915, less common in 1916. This is the only gymnodinian found here in the winter months, but then only rarely. It turns up singly nearly all the year round. Many abnormalities and deformities occur and a variety of shapes is seen.

(41) N.R. *G. pseudonoctiluca* Pouchet (Fig. 3). To this species I refer one which agrees well with one condition of the above species, but which I never saw with the long contractile tentacle described by Pouchet (1885). It only occurred twice, the first time in medium tow nettings in July, 1915, and the second time in the water samples in June, 1916. It is rather smaller than the type (length 0·10 mm.). The ventral surface on each side of the longitudinal groove is pulled out into a flap, the left flap slightly longer than the right. The bright yellow chromatophores radiate from the centre. The longitudinal groove is more marked than in Pouchet's figures. The nucleus is in the centre of the body.

(42) *G. viridis* n. sp. (Fig. 4). Closely related to the last species is one also found only singly and which is less than half the size. In shape it is much like *G. pseudonoctiluca* with a cap-like anterior end; the longitudinal groove, however, reaches back slightly over the dorsal surface posteriorly so that the hind end is divided. The chromatophores are of a greenish yellow colour, not bright yellow as in *P. pseudonoctiluca*. Length 0.06 mm. Occurred once in June.

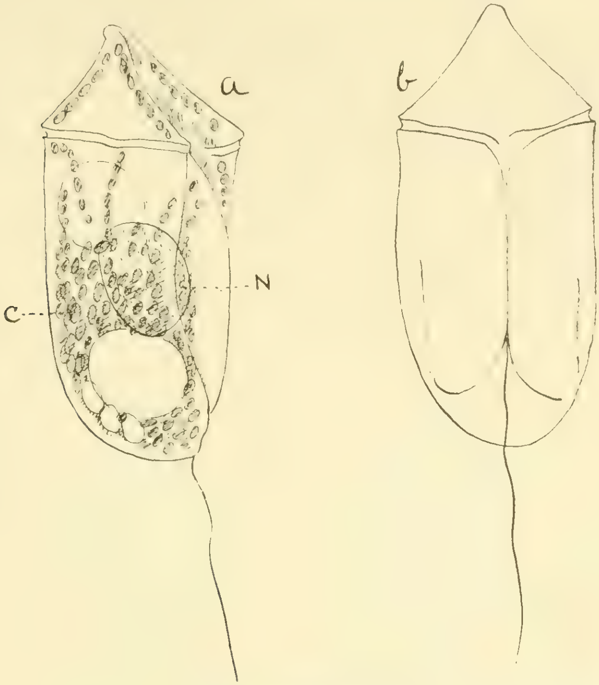


FIG. 3.—*Gymnodinium pseudonoctiluca* Pouchet. × 466.
a side view, *b* ventral view. N=nucleus. C=chromatophores.

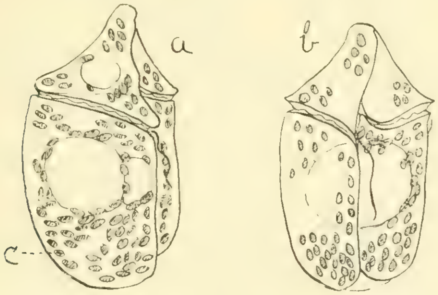


FIG. 4.—*Gymnodinium viridis* n. sp. × 466
a side view, *b* ventral view. C=chromatophores.

(43) *G. achromaticum* n. sp. (Fig. 5). Related to *G. viridis* but without chromatophores. Perfectly colourless and transparent, transverse groove conspicuously left-handed, longitudinal groove reaching to the extreme posterior end. Apex somewhat excentric. Body covered with longitudinal striæ. Nucleus posterior. One specimen only in July, 1915.

(44) N.R. *G. rhomboides* Schütt (Fig. 6). One of the commonest in this area appears to be the species figured by Schütt (1895, Plate XXI, Figs. 63, 1 and 2) with the above name. Apparently no description of it exists except the short diagnosis in "Nordisches Plankton" (p. 99). Certain aspects of my specimens agree very closely with Schütt's figures, and I have therefore taken the name given by him rather than create a new one.

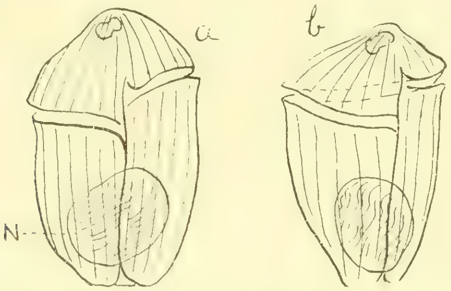


FIG. 5.—*Gymnodinium achromaticum* n. sp. × 466. *a* ventral view, *b* side view. N=nucleus.

The species referred to by Dogiel (1906) as *Gymnodinium spirale* v. *obtusum* is from his figures certainly a true *Gymnodinium* and not a *Spirodinium*, to which now *G. spirale* and all its varieties have been transferred. The original figures by Bergh of *G. spirale* show it to be a *Spirodinium* with the ends of the transverse groove far apart, moreover Schütt's figure of v. *obtusum* shows also the same character. Dogiel's species probably belongs to *G. rhomboides* or else some closely related form. His specimens, however, are very much larger than mine. His figures of the stages in division show it in another form which is also common with us and which I have found in division and very similar to Dogiel's figures. Schütt's figure 63, 1 is also of this type, and apparently this is the form before and during division. These two forms I have therefore placed together as *Gymnodinium rhomboides*. The body is elongated, oval or rhomboidal, the transverse groove is only slightly displaced and left-handed, the longitudinal groove is inconspicuous. The whole surface is covered with longitudinal striæ, those on the anterior portion being further apart than those posteriorly. Remains of food in a ball is often seen in the hind portion of the body. Nucleus anterior. The body colourless with no chromatophores. Its food consists very often of *Phæocystis pouchetii* when that flagellate is abundant, at other times of diatoms ; remains of *Thalassiosira* and *Coscinodiscus* were also found inside the body. Division takes place in the free state as described and figured by Dogiel.

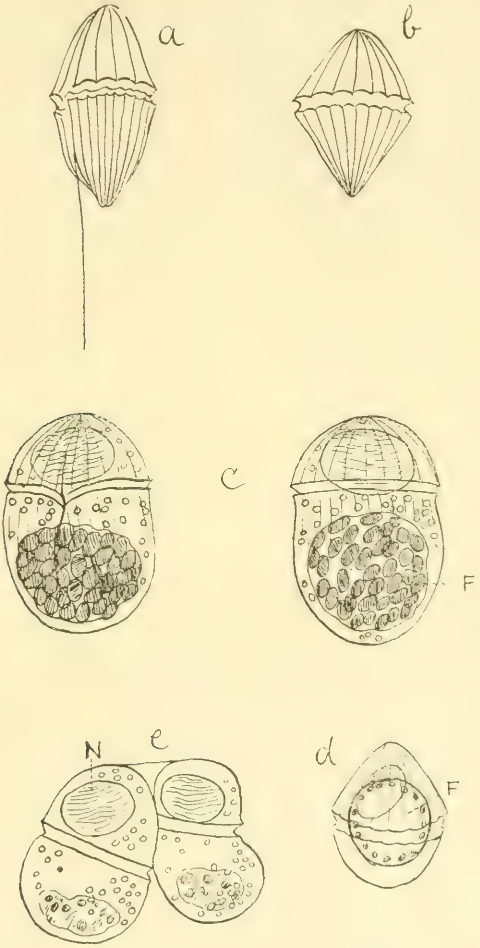


FIG. 6.—*Gymnodinium rhomboides* Schütt. × 466

a side view, *b* dorsal view, *c* ventral and dorsal views of older forms containing food masses of *Phæocystis*, *d* young form containing a *Thalassiosira*, *e* division. N = nucleus. F = food.

This is perhaps the commonest gymnodinian and occurs close to the shore as well as beyond the Breakwater. Length of body 0·040 mm. to 0·050 mm

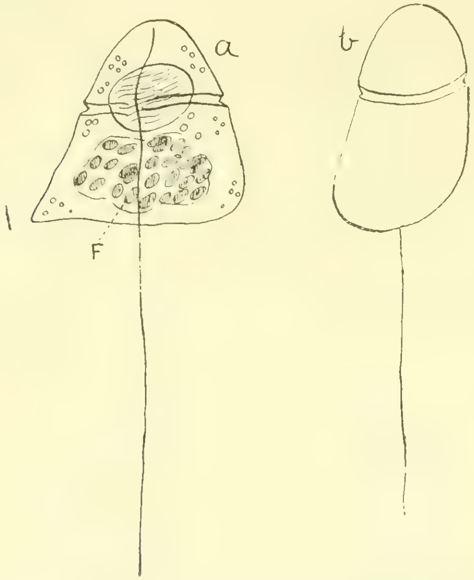


Fig. 7.—*Gymnodinium triangularis* n. sp. × 466.
a ventral view showing contained *Phæocystis*, *b* side view. F = food.

(45) *Gymnodinium triangularis* n. sp. (Fig. 7). Closely related to *G. rhomboides*, but triangular in outline (the base of the triangle posterior) and without longitudinal striæ on the body. Rare in water samples in May. This species had also been feeding on *Phæocystis pouchetii*, remains of which were recognisable inside it. Length 0.045 mm.

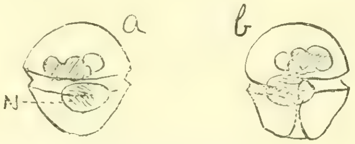


Fig. 8.—*Gymnodinium minor* n. sp. × 466.
a dorsal view, *b* ventral view. N = nucleus.

(46) *Gymnodinium minor* n. sp. (Fig. 8). This little species is transparent and destitute of any sculpture. It is nearly spherical but with the posterior end slightly narrower than the anterior. Transverse groove left-handed and only slightly displaced, longitudinal groove reaching to the posterior end. Nucleus nearly

central; green masses, probably food material, at the anterior end. Length 0·028 mm. Occasionally in water samples May to July.

(47) *Gymnodinium filum* n. sp. (Fig. 9). Body long and narrow, tapering to a thread-like point posteriorly. Anterior end conical. Transverse groove almost straight, longitudinal groove reaching about three-quarters of the way to the posterior end. Nucleus behind the centre. A dark brown mass (probably food remains) in front of and at the side of the nucleus. One specimen was found with no coloured body. Body clear and colourless with no striæ. Length 0·065 mm. Rare in water samples July, 1915. Very fragile and easily collapses.

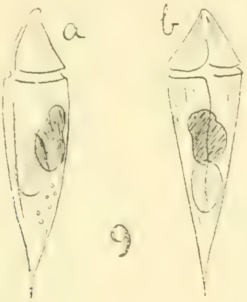


Fig. 9.—*Gymnodinium filum* n. sp. × 466
a side view, *b* ventral view.

Genus Spirodinium Schütt.

(48) N.R. *Spirodinium fissum* (Levander) Lemmermann. Occurs occasionally in August and September in water samples. Conspicuous from its yellow colour and peculiar dorso-ventral flattening. Division in the free state was noticed in September.

(49) N.R. *Spirodinium spirale* (Bergh) (Fig. 10). This species is exceedingly common in the water samples in many varieties. The typical form which agrees with Pouchet's description and figure (1885, p. 67, Plate IV, Fig. 30) is usually much smaller than his specimens and generally colourless, although bright yellow examples are sometimes seen, such as Pouchet himself observed occasionally. The yellow examples are always blunter at the apex than the type which is pronouncedly acuminate. My specimens, including the yellow forms, measure generally 0·04 mm. to 0·06 mm., whereas Pouchet (1883–85) gives 0·10 mm. as the typical size. The longitudinal striations are characteristic,

and green remains of food are sometimes to be found inside the body, also small roundish masses of fat.

The variety *acutum* Schütt (Plate XXI, Fig. 66) is also found, which seems to be close to the typical form and more nearly the size of Bergh's (1882) and Pouchet's specimens. Length of this variety 0·14 mm. One specimen which occurred in August, 1915, was coloured a beautiful carmine, the colour running along the lines of the striæ in droplets. Other specimens are quite colourless.

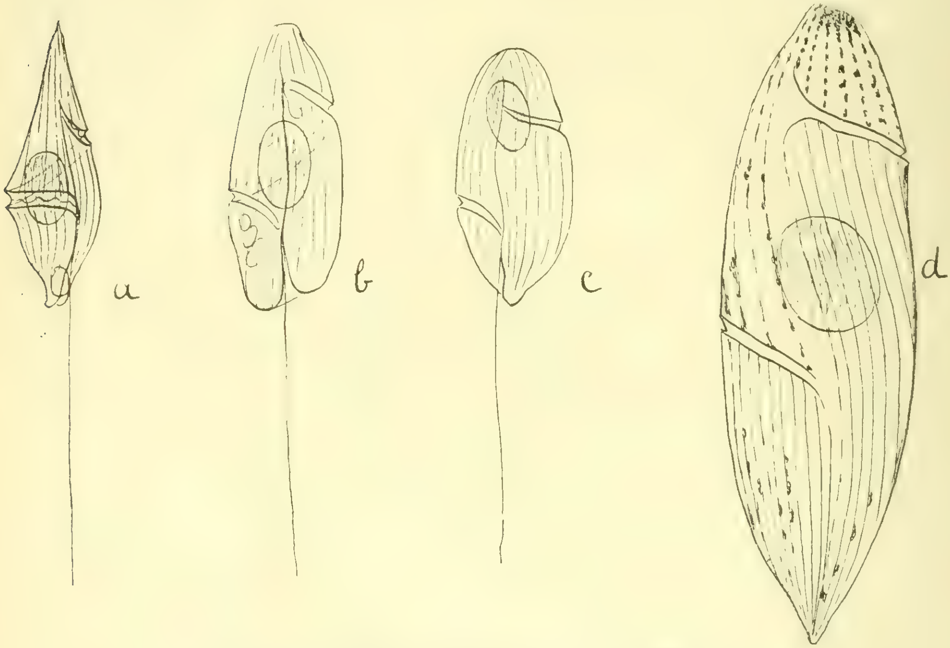


FIG. 10.—*Spirodinium spirale* (Bergh). × 466.
a typical form, *b* and *c* v. *obtusum* Schütt, *d* v. *acutum* Schütt.

The variety *obtusum* Schütt is also common but of small size. Length 0·06 mm. usually. Characterised by its blunt apex.

(50) *Spirodinium concentricum* n. sp. (Fig. 11). This species is characterised by the sculpture of concentric striæ on the body, the longitudinal striæ being arranged concentrically round a certain point at the side or on the dorsal surface. Body colourless. Grooves and shape of the body very much like the variety *obtusum* of the preceding species. A large and a small form exist, the larger form being several times the size of the smaller. Both rare, only in the summer of 1915.

(51) N.R. *Spirodinium crassum* (Pouchet) (Fig. 12). I have referred to this species a somewhat rare form which is definitely smaller than the type, length 0·075 mm. (type 0·12–0·2 mm. Pouchet). In shape and contour of the furrows it corresponds and has a diffuse colouring of brownish red beginning at the apex and following the transverse furrow. Faint longitudinal striæ are present; transverse furrow with its ends widely separated, longitudinal furrow weakly developed. Nucleus posterior. Interior of body full of large granules. Occurs occasionally in June.

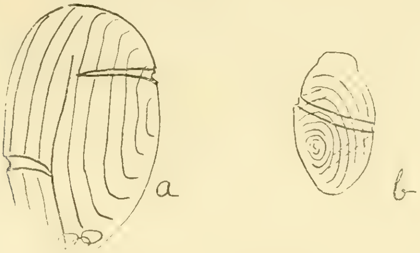


FIG. 11.—*Spirodinium concentricum* n. sp. × 466.
a large form, *b* small form.

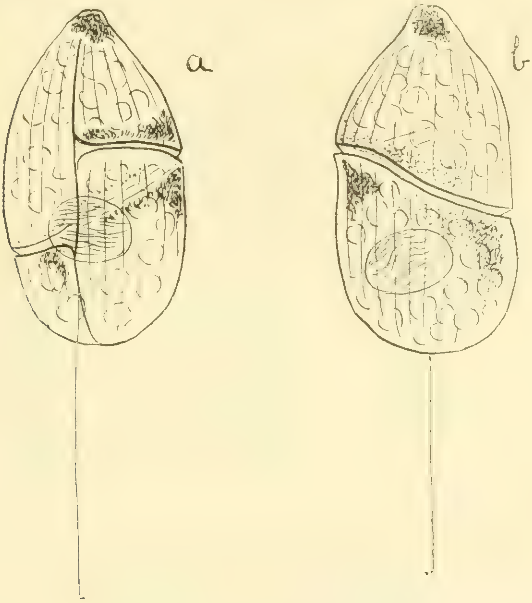


FIG. 12.—*Spirodinium crassum* (Pouchet). × 466.
a ventral view, *b* dorsal view.

(52) *Spirodinium glaucum* n. sp. (Fig. 13). This is a very common species, perhaps the commonest Spirodinium in this area. It begins in May, having its maximum in May and June and persists till October. A large yellow body posteriorly is characteristic, although this may be absent in young forms and possibly is only food remains, although it is always the same colour and in the same place. These yellow bodies are also sometimes absent in divisional stages. The body is elongated with a long anterior and short posterior portion, with a few wide apart longitudinal striæ. Transverse furrow with the ends wide apart; longitudinal furrow short and with the appearance of a

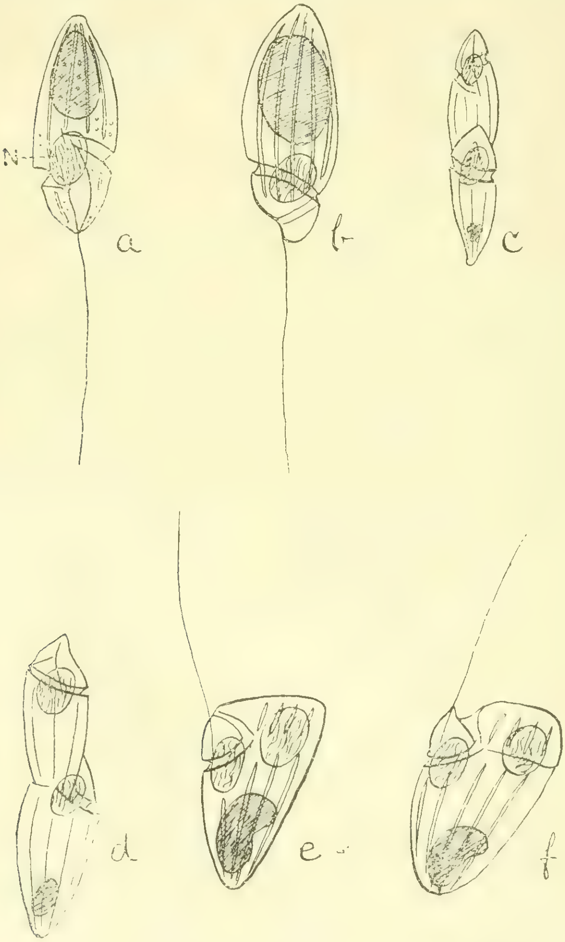


FIG. 13.—*Spirodinium glaucum* n. sp. × 466.
a ventral view, *b* dorsal view, *c–f* division stages. N=nucleus.

three-cornered bite having been taken out of the posterior end. This species is rather like *G. teredo*, with the exception of the chromatophores which are numerous in the latter species. Cell colourless except for the yellow mass. Nucleus in the region of the transverse furrow. Divisional stages are often seen in the free state, one individual pushing part of its body backward so that a chain of two is formed very much like the figure given by Pouchet of the division of *S. spirale* (loc. cit.). Earlier stages in division show that the longitudinal flagellum persists as is described by Dogiel in his *Gymnodinium spirale* v. *obtusum*. A growth then takes place at the side of the whole body, so that the cell is very much swollen transversely; then division takes place, beginning at the posterior end as a groove and half the cell is pushed backwards so that the chain of two individuals is formed, one attached to the side of the posterior end of its fellow by its extreme anterior end. After division the individuals are small and may or may not contain yellow bodies. In one case the yellow body appeared to be dividing at the same time as the cell, which perhaps shows it to be a chromatophore.

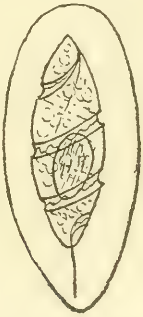


FIG. 14.—*Cochlodinium pulchellum* n. sp. × 466.

Genus COCHLODINIUM Schütt.

(53) N.R. *Cochlodinium helix* (Pouchet). Occurs occasionally in the water samples in August, sometimes free, sometimes enclosed in a spacious perfectly transparent covering.

(54) N.R. *Cochlodinium pellucidum* Lohmann. Rare. In the water samples in July and August.

(55) *Cochlodinium pulchellum* n. sp. (Fig. 14). This species was found once only in the water samples from 7 fathoms, August, 1915. It is perfectly colourless and contained in a roomy trans-

parent case in which it rotates freely on its longitudinal axis. It is fusiform in shape, and pointed in much the same way at both ends. The transverse furrow makes three complete turns and is deeply grooved. The longitudinal furrow is inconspicuous, making over one turn round the body. Nucleus nearly central. Length of body 0·05 mm., length of case 0·65 mm. This species is very similar to *Pouchetia fusus* Schütt, but without the conspicuous lens and stigma of that form.

Genus POUCHETIA Schütt.

(56) N.R. *Pouchetia armata* Dogiel (1906). This species, with its characteristic stinging capsules, is common in the water samples, especially in May and June. It is sometimes contained in a case, sometimes, and more usually, free. Division into two within the case was seen. So far this species has only been recorded for the Mediterranean.

(57) N.R. *Pouchetia parva* Lohmann. This is fairly frequent in summer, especially in June. The case fits very close to the body, much closer than in *P. armata*. Division in the case is often seen. This species is very like Pouchet's figure (1885) of *P. polyphemus* v. *nigra*, the pigment, however, in his species is red and this is always black.

(58) N.R. *Pouchetia fusus* Schütt (1895). Occurs rarely in September. Conspicuous from its elongated body and large lens with dark red pigment. In one case the pigment mass was breaking up into small red spots. The specimens seen were always free.

Genus POLYKRIKOS Bütschli.

(59) N.R. *Polykrikos Schwarzii* Bütschli. Occurs occasionally in tow nettings and water samples from May throughout the summer.

PYROCYSTEÆ Apstein.

Genus PYROCYSTIS Murray.

(60) *Pyrocystis lunula* Schütt. Occurs occasionally in tow nettings in August and September in various stages of division in the semilunar cases.

Incertae sedis.

(61) N.R. *Oxyrrhis marina* (Duj.). The position of *Oxyrrhis* is still a vexed question, and although Senn (1910) regards it as a true peridinian, the view is not universally accepted (see Klebs, 1912). In my opinion it is more of a peridinian than a true flagellate, the division

stages of *Gymnodinium* and *Spirodinium* being closely related to those of *Oxyrrhis*. *Oxyrrhis marina* occurs sparingly in the water samples, but is to be found in great abundance in cultures in the laboratory in which it thrives with the greatest ease. In cultures of *Nitzschia closterium* especially it flourishes in enormous numbers, the body being full of this diatom on which it feeds.

LITERATURE.

1882. Bergh, R. S. "Der Organismus der Cilio-flagellaten." Morph. Jahrb., Bd. 7.

1906–8. Bygrave, W. "Report on the Plankton of the English Channel in 1906." M. B. A. International Fisheries Investigations, 1906–8, Cd. 4641.

1897. Cleve, P. T. "Plankton Researches in 1887." Kongl. Svensk. Vetensk. Akademiens Handlingar, Bd. 32, No. 7.

1900. —— "The Plankton of the North Sea, English Channel and the Skagerak in 1899." *Ibid.*, Bd. 32, No. 2.

1906. Dogiel, V. "Beitrage zur Kenntnis der Peridineen." Mitt. aus der Zool., Station Neapel, 18 Bd.

1903*a*. Gough, L. "Plankton, English Channel, February, May, August, and November, 1903 and 1904." Bull. d. Rés. acq. pend. l. c. période pub. p. l. Conseil International pour l'Exploration de la Mer.

1903*b*. —— "Report on the Plankton of the English Channel in 1903." M.B.A. International Fisheries Investigations, Cd. 2670.

1905. —— Cd. 3837.

1912. Gran, H. H. "The Plankton Production of the North European Waters in the Spring of 1912." Bull. Planktonique, 1912.

1907–14. Herdman, W. A. and Scott, A. "An Intensive Study of the Marine Plankton around the South End of the Isle of Man." Parts I–VIII. Reports for 1907–14 of the Lancashire Sea Fisheries Laboratory.

1912. Klebs, G. "Ueber Flagellaten und Algen—ähnliche Perideen." Verhandlungen der Naturhistorisch-medizinischen Vereines zu Heidelberg, N.F. Bd. 11, July, 1912.

1908. Lohmann, H. "Untersuchungen zur Feststellung des Vollständigen Gehaltes des Meeres an Plankton." Wissenschaftliche Meeresunterserchungen h.v.d. komm. z. wiss. unters. d. deutschen Meere in Kiel, 1908.

1913. Mangin, L. "Sur la Flore planctonique de la rade de Saint-Vaast-la-Hougue 1908–12." Nouvelles Archives der Muséum d'Histoire naturelle, 5 Sér., 1913.

1910. Meunier, A. "Duc d'Orléans, Campagne Arctique de 1907." Microplankton des Mers de Barents et de Kara.

1908. Paulsen, O. "Nordisches Plankton," Vol. VIII. "Peridiniales."

1883. Pouchet, G. "Contribution à l'Histoire des Cilio-flagellés." J. de l'Anat. et de la Phys., 1883.

1885. —— "Nouvelle contribution à l'histoire des Péridiniens marins."

1910. Senn, G. "Oxyrrhis, Nephroselmis und einige Euflagellaten." Zeitsch. Wissens. Zool., Bd. 97.

1895. Schütt, F. "Die Peridinien des Plankton Expedition." I Thiel.

Some Parasites of *Sagitta bipunctata.*

By

Marie V. Lebour, M.Sc.,

Assistant Lecturer in Zoology, Leeds University.
Temporary Naturalist at the Plymouth Laboratory.

With text Figures 1-6.

Sagitta has been several times noticed as a host for various parasitic worms, notably a larval nematode and several trematodes. Larval cestodes have also been seen in it. It is exceeding voracious and apparently eats almost any animal food, especially its own species and small crustacea, so that it is not to be wondered at if it forms a convenient intermediate host for many worms, and as *Sagitta* itself is an important fish food it naturally follows that the adults of these parasitic worms are usually found in fish as their final hosts. So far, however, the life histories of the larval forms hitherto found have not been determined, so we are pleased to be able to identify two trematodes belonging to well-known species which inhabit *Sagitta* as intermediate host and fish as the final host.

Busch (1851) and Leuckart and Pagenstecher (1858) have described several larval trematodes and a nematode from *Sagitta*, Ulianin (1871) a nematode, and Pierantoni (1913) a nematode. The latter nematode is probably the same worm found in *Sagitta* in Plymouth Sound. Busch's description of a nematode in *Sagitta* is too vague to recognise it, and unfortunately Ulianin's paper has not been available for reference. Leuckart and Pagenstecher mention two larval trematodes from *Sagitta germanica* (=*Sagitta bipunctata* Q. and G.), one a monostome and the other a distome. Although these are figured, they are neither described nor named. The distome (Plate XXI, Fig. 9) is probably the larval *Derogenes varicus* which occurs in *Sagitta bipunctata* in Plymouth Sound. Busch's trematode larvæ found in *Sagitta cephaloptera* (=*Spadella cephaloptera*) were identified by him as *Distomum papillosum* Diesing (=*Distomum beroë* Will (1844)) and two new species, one of which he names *Distomum fimbriatum* and the other *Distomum crassicaudatum*. *Distomum papillorum* appears to be a larval *Hemiurus*, *D. fimbriatum* is not described sufficiently to recognise, and *D. crassicaudatum* seems also to be a species of *Hemiurus*. As *Derogenes* is a genus closely related to *Hemiurus* it is interesting to find that both inhabit *Sagitta* as an intermediate host.

In Plymouth Sound the only species of *Sagitta* is *S. bipunctata* Q. and G. In 1916 Mr. Smith called my attention to the number of parasitic nematodes in it from old plankton samples. Afterwards it was found to be very common in the fresh samples and quite the commonest parasite of *Sagitta*. It is a larval *Ascaris*, and in all probability is the same species as that described by Pierantoni (1913) from *Sagitta* in the Bay of Naples, and he has also found them from Villafranca, Wimereux and Trieste. In his brief note on the worm he suggests that it may be identical with an *Agamonema* described by Stossich from a *Ranzana*, one of the *Molidæ*. The final host of the nematode from the Plymouth *Sagitta* is quite unknown, but one would expect it to be something common judging from the frequency of its occurrence.

This larval *Ascaris* occupies the body cavity of *Sagitta*, lying lengthwise, and sometimes is three-quarters the length of its host. The figure here given (Fig. 1, Plate I) is from a small specimen. The body is colourless and measures 3 to 17 mm. in length and is very narrow. The anterior end is provided with a large larval hook for boring; the œsophagus is long and prolonged behind by the side of the intestine into a blind œsophageal sac: the intestine which occupies nearly the whole of the body, since the reproductive organs are not yet present, gives off forwards a second blind sac, the blind intestine, which runs along by the side of the œsophagus. The anus is near the tail, the latter ending in a small sharp spike. The brain is plainly seen as a broad band anteriorly running round the œsophagus, and just behind it is the excretory pore from which can be traced the thin excretory duct. A large proportion of the Sagittæ brought in by the tow nets is infected with this nematode.

Two trematode larvæ are also common in the local *Sagitta*, the larva of *Derogenes varicus* (O. F. Müller) and the larva of *Pharyngora bacillaris* (Molin). Both of these inhabit common fish in their adult state.

Derogenes varicus is one of the commonest trematodes with a wide distribution, and occurs in a number of different fish. Odhner (1906) states that about a dozen and a half northern fish are recorded as its hosts. Nicoll (1914) quotes twenty-eight different fish as its hosts from the Channel, *Cottus*, various *Gadidæ* and a few Plemonectids are the common hosts. It occupies the stomach of these fish.

Levinsen (1881) records the larval form of this trematode from *Harmothoë imbricata*, and finds the remains of this annelid in the stomach of *Cottus*. It is very interesting to find the larva in the Sound inhabiting

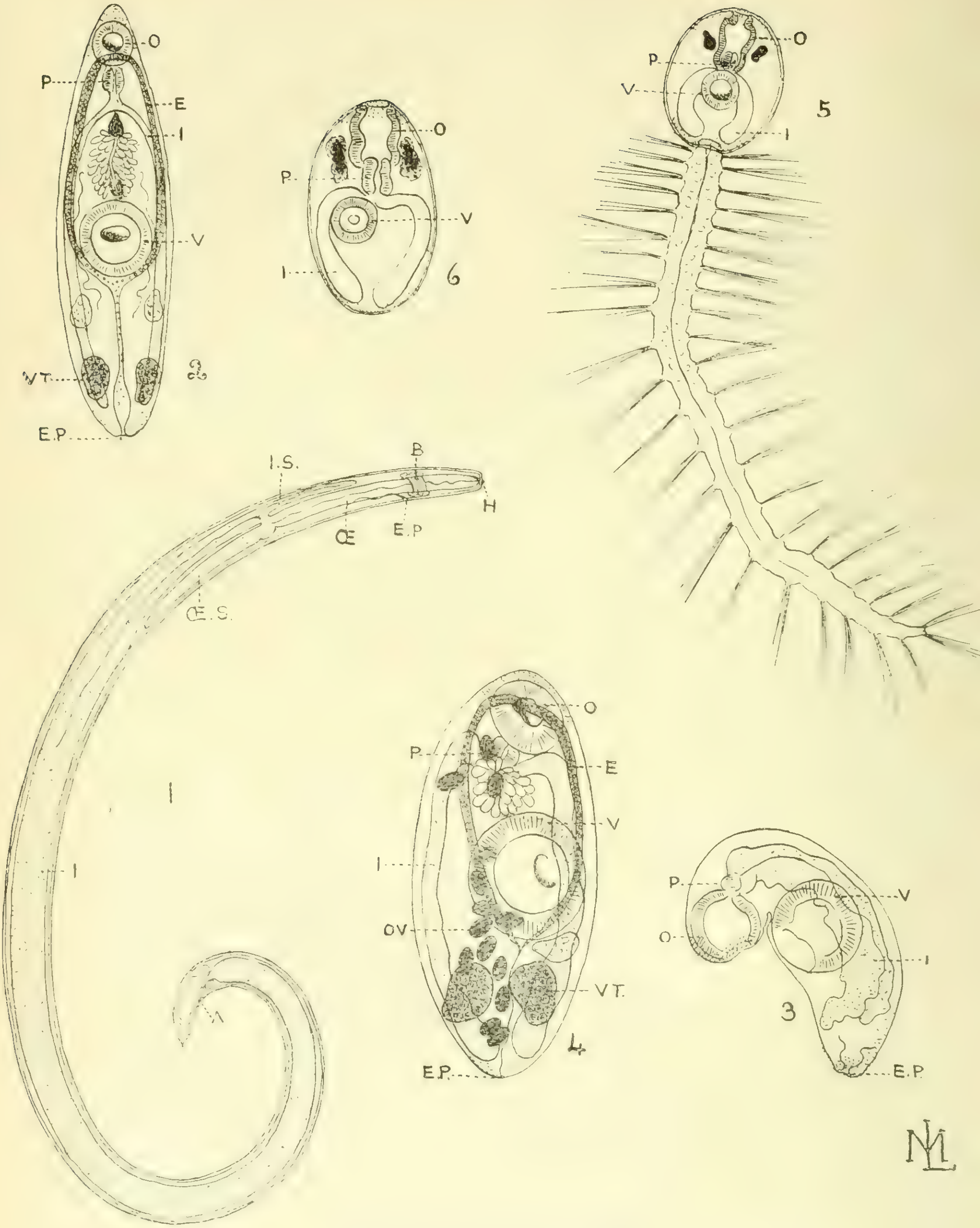
Sagitta, which looks as if *Derogenes varicus* had a different intermediate host in the open sea than it does near the shore.

The larger larvæ of *Derogenes varicus* which are found in *Sagitta* have nearly all the adult characters (Plate I, Fig. 2), and the smaller ones are found in intermediate stages and are easily recognised. That we have to do with the true *Derogenes varicus* is placed beyond a doubt by the occurrence of a mature specimen in *Sagitta* which bears eggs (Plate I, Fig. 4). A parallel case is found in *Echiurus pallasii* (Greef, 1879) which contained a mature *Distomum*, *D. echiuri* Greef, and other cases of trematode larvæ producing eggs have been recorded, although they are rare. The present specimen has only a few eggs, whereas in the ordinary adult stage in a fish they are very numerous.

A curious fact noticed is that all these larval *Derogenes varicus* are beset with small spines, whereas it is a characteristic of the adult that although it has sometimes a wrinkling of the skin it is unarmed and usually smooth. It is possible that these wrinkles may be the remains of the spines fused together. The spines are specially distinct in the younger specimens.

These larval *Derogenes varicus* are nearly always found in the region of the ovary of *Sagitta,* and there is rarely more than one present in each individual, although one may be present at the same time as the larval *Ascaris* described above.

Pharyngora bacillaris (Molin), the second larval trematode found in *Sagitta,* is a common parasite of the mackerel in its adult state, and has been found in the whiting and also a few other fish, except in the whiting, in an immature state. Nicoll (1914) found many thousand of the immature form in *Cyclopterus lumpus.* These had probably got in with the food and would not come to maturity. The late cercaria stage of this worm was found frequently in medusæ (Lebour, 1916) and free in the plankton (Nicoll, 1910). It was also found in ctenophores, so it is evidently not particular as to its intermediate host. Cercariæ of all ages were found in *Sagitta* occupying usually the region of the ovary, as is the case with *Derogenes varicus*, but sometimes it is inside the alimentary canal, which looks as if *Sagitta* swallows it and afterwards it migrates through the intestinal wall into the region of the ovary. What I have no doubt is the free-swimming cercaria of this trematode was found once in tow nettings on January 28th, 1916. *Sagitta* from the same samples contained these cercariæ without their tails, and it could be traced up to the ordinary *Pharyngora* late cercaria stage, such as was found in the medusæ and free in the plankton. The free-swimming cercaria is extremely interesting (Fig. 6). It is provided with a large tail several times the length of the body and armed with bunches of


O
P
E
I
V
VT
E.P
2
O
P
V
I
6
O
P
V
I
5
I.S.
B
H
Œ
E.P
Œ.S.
1
I
A
O
P
E
V
I
OV
VT.
E.P
4
P
V
O
I
3
E.P

EXPLANATION OF FIGURES.

Fig. 1.—Larval *Ascaris* from *Sagitta* ×60. A anus, Œ œsophagus, Œ.S blind sac from œsophagus, B brain, I intestine, I.S blind sac from intestine, H boring hook.

Figs. 2–3.—*Derogenes varicus* from *Sagitta* ×60.

Fig. 4.—Ditto containing eggs ×60.

Fig. 5.—Free-swimming cercaria of *Pharyngora bacillaris* ×60.

Fig. 6.—Cercaria of *Pharyngora bacillaris* from *Sagitta* ×60. O oral sucker, V ventral sucker, E excretory duct, E.P excretory pore, I intestine, P pharynx, VT vitellaria, OV ova.

long bristles placed at regular intervals and giving it the appearance of an annelid. The tail is an efficient swimming organ, and the bristles no doubt serve for keeping the whole animal floating. Two large kidney-shaped black eyes are conspicuous, the oral sucker has the typical *Pharyngora* form which is more like a pharynx in shape, the true pharynx leading from it to a short œsophagus and intestinal cœca reaching to the end of the body. The whole body is covered with small spines. In the specimens inside *Sagitta* the eyes have begun to show diffuse pigment as in the older specimens instead of its being in a thick black mass as in the free-swimming form.

Neither *Derogenes varicus* nor *Pharyngora bacillaris* have been found encysted, and it is presumed that the encysted stage is omitted as the cercariæ develop in *Sagitta* and the other hosts into a late form which is ready to enter its final host. The first host which presumably is a mollusk is yet to be discovered for both of these trematodes.

Two larval cestodes were also found in *Sagitta* from the Sound, one with four suckers and one with none. These were not identified. It is evident that we have in *Sagitta* an exceptionally good host for many parasites, and probably further investigation would be amply repaid.

LITERATURE.

1851. Busch, W. "Beobacht, über Anat. und Entwickl. Wirbelloser Seethiere," Berlin, p. 98.

1879. Greef, R. "Die Echiuren." Nova Acta der Ksl. Leop. Carl. Deutschen Akad. d. Naturf. XLI., Pt. II, No. 1.

1916. Lebour, M. V. "Medusæ as Hosts for Trematodes." J. M. B. A., Vol. XI, No. 1.

1858. Leuckart, R. und Pagenstecher, A. "Untersuchungen über niedere Seethiere." Müller's Archiv., p. 559.

1881. Levinsen, G. M. R. "Bidrag til Kundskab om Grönlands Trematodfauna." Over. K. D. Videns. Selsk. Forh., p. 80.

1910. Nicoll, W. "On the Entozoa of Fishes from the Firth of Clyde." Parasitology, Vol. III, No. 3.

1914. Nicoll, W. "The Trematode Parasites of Fishes from the English Channel." J. M. B. A., Vol. X, No. 3.

1906. Odhner, T. "Die Trematoden des Arktischen Gebietes." Fauna Arctica.

1913. Pierantoni, U. "Sopra un Nematode Parassita della 'Sagitta,' e sul suo probabile ciclo evolutivo." Trans. from IX. Congrès International de Zool. tenu a Monaco, p. 663.

1871.* Ulianin. "Ueber die pelagische Fauna des schwarzen Meeres." Verhandl. d. Moskauer Freunde d. Natur.

1844. Will, F. "Ueber Distoma beroës." Archiv. f. Naturgesch., Vol. X, p. 343.

* Not seen by the present writer.

Post-Larval Teleosteans collected near Plymouth during the summer of 1914.

By

E. J. Allen, D.Sc., F.R.S.,
Director of the Plymouth Laboratory.

With 8 Figures in the Text.

In Volume X, No. 2, of this Journal issued in June, 1914, Mr. R. S. Clark published an account of the post-larval fishes collected during the years 1906 to 1913 with the Petersen Young-fish Trawl in the neighbourhood of Plymouth. Similar collections were continued regularly under Mr. Clark's supervision, with the assistance of Mr. E. Ford and Mr. F. M. Gossen, from April to July, 1914, and two or three hauls were made in August and September of that year. At the beginning of August Mr. Clark joined Sir Ernest Shackleton's expedition to the Antarctic and left Plymouth in the "Endurance." The young fishes had for the most part been picked out from the general material collected by the young-fish trawl by Messrs. Ford and Gossen, and it is this collection of young fishes which forms the subject of the present report.

In drawing up the report I have followed closely the arrangement adopted by Mr. Clark for the earlier material, and it should be regarded throughout as being supplementary to his paper (**1914**). For most of the important fishes I have given a monthly summary of the number of specimens captured during the whole period 1906 to 1914, which includes both the figures given by Clark and those now added. The average number of specimens taken per haul of the trawl has also been given for each month. For many reasons, however, these averages cannot claim any great degree of accuracy, but they are, I think, useful as giving a general idea of the relative frequency in the different months. The following sources of error must be borne in mind when drawing conclusions from the averages. The duration of the hauls has been in most cases twenty minutes, but there are a few instances where the time was fifteen minutes and a few where it was thirty minutes. The error introduced by regarding all the hauls as of equal duration will be so small that it will hardly show in the average figures given.

A more important error will be caused by the fact that the hauls are not distributed with any uniformity over the whole area. The great majority were, however, made outside the 20-fathom line where the conditions are moderately uniform, but in calculating the averages these have not been separated from the hauls made nearer the shore and in the bays.

Some of the hauls were made at the surface, some at midwater, and some near the bottom, whilst some few are night hauls, which seem to yield larger numbers, especially at the surface, than those made during the day. These circumstances will all tend to diminish the accuracy of the averages, but they do not, I think, destroy their more general significance.

The number of hauls made in each month varies considerably, but from May to September the totals are fairly large (Table II). The number of hauls made in the different years for any given month, as will be seen from the same table, varies so very much that it is not possible to make reliable comparisons of the frequency of any species from year to year.

Another source of error is introduced by the fact that the material of which the young-fish trawl is constructed is not altogether satisfactory, and the size of the mesh often differs considerably in different samples, so that even two new trawls may have different catching powers. With use also the material shrinks badly, the meshes become smaller and the amount of water filtered through the net (and hence the catching power) is greatly diminished. All these circumstances make the numerical results approximate only.

Table I gives the list of stations at which hauls were made in 1914. The Chart Area, to which each haul is assigned, is that shown on the chart published in Clark's Report (**1914**).

TABLE I. LIST OF STATIONS.

Explanation of abbreviations. S.=surface. M.=midwater. B.=bottom. M.H.=midnight haul (between 10 p.m. & 2 a.m.).

No. of haul.	Date.	Depth of capture.	Duration of haul in minutes.	Locality.	Total depth in fathoms.	Chart area.
V.	29.iv.14	B.	20	Eddystone S. by W. 4 miles	28	S.
VI.	,,	M.	20	Rame N.E. by E. $4\frac{1}{2}$ miles	28	S.
VII.	,,	S.	20	Rame N.E. $3\frac{1}{2}$ miles	28	T.
VIII.(1)	8.v.14	M.	25	Cawsand	∠10	T.U.
VIII.(2)	,,	M.	20	Cawsand	∠10	T.U.
IX.(1)	15.v.14	M.	20	Bigbury Bay (west part)	ca. 10	W.Y.
IX.(3)	,,	S.	20	Bigbury Bay (central)	ca. 14	Y.
IX.(5)	,,	B.	20	Bigbury Bay (east of B. Island)	ca.12–14	Y.
X.	19.v.14	M.	20	Eddystone N. by E. 5 miles	37	O.
XI.	,,	S.	20	Eddystone N. $5\frac{1}{2}$ miles. M.H.	38	R.
XII.	,,	S.	20	Eddystone N. 6 miles. M.H.	39	R.
XIII.	,,	M.	20	Eddystone N. $6\frac{1}{2}$ miles. M.H.	39	Q.
XIII.a	22.v.14	—	20	Eddystone S.W. 3 miles	28	S.
XIV.	25.v.14	M.	20	Eddystone N. 4 miles. M.H.	35–36	R.
XV.	,,	S.	20	Eddystone N. $4\frac{1}{2}$ miles. M.H.	36	R.
XVI.	,,	S.	20	Eddystone N. 5 miles. M.H.	37	R.
XVII.	3.vi.14	B.	20	Rame E. 4 miles	26	T.
XVIII.	,,	B.	20	Rame E. $4\frac{1}{2}$ miles	27	M.
XIX.	,,	M.	20	Rame E. $4\frac{1}{2}$ miles	27	M.
XX.	10.vi.14	S.–M.	20	Rame E. 7 miles. M.H.	27	M.
XXI.	11.vi.14	M.	20	Rame E. 7 miles. M.H.	27	M.
XXII.	,,	M.–B.	20	Rame E. 7 miles. M.H.	27	M.

TABLE I. LIST OF STATIONS.

Explanation of abbreviations. S. = surface. M. = midwater. B. = bottom. M.H. = midnight haul (between 10 p.m. & 2 a.m.).

No. of haul.	Date.	Depth of capture.	Duration of haul in minutes.	Locality.	Total depth in fathoms.	Chart area.
XXIII.	11.vi.14	B.	20	Rame E. 7 miles. M.H.	27	M.
XXIV.	16.vi.14	B.	20	Between Penlee and Rame Head	ca. 15	T.
XXV.	,,	B.	20	Rame E. 1½ miles	22	T.
XXVI.	,,	B.	20	Rame E. 3 miles	23	T.
XXVII.	,,	M.	20	Rame E. 5 miles	27	M.
XXVIII.	,,	B.	15	Eddystone S.S.W. 3 miles (Mosquito net YFT.)	29	S.
XXIX.	17.vi.14	B.	20	Off Rame Head 2 miles	15	T.
XXX.	,,	M.	20	Off Rame Head 2 miles	11	T.
XXXI.	,,	M.	20	Rame Head N. by E. 4½ miles	28	S.
XXXII.	,,	S.	20	Eddystone S.W. 2 miles	29	S.
XXXIII.	19.vi.14	M.	20	Looe Island N.N.E. 5 miles	28	M.
XXXIV.	,,	M.	20	Looe Island N. by E. 5 miles	29	M.
XXXV.	,,	M.	20	Eddystone S.S.E. 4½ miles	28	N.
XXXVI.	24.vi.14	B.	20	Eddystone W. by N. ½ mile	23	S.
XXXVII.	,,	B.	20	Eddystone N.N.W. 1 mile	32	S.
XXXVIII.	,,	M.	20	Eddystone N. 2½ miles	35	R.
XXXIX.	,,	S.	20	Eddystone N. by E. 3½ miles	37	R.
XLI.	26.vi.14	B.	20	Eddystone N.E. by E. 3½ miles	36	R.
XLII.	29.vi.14	B.	20	Stoke Point N.E. 4 miles	24	X.
XLIII.	,,	B.	20	Stoke Point N.E. by N. 5 miles	27	X.
XLIV.	,,	M.	20	Bolt Tail E. by N. 5 miles	25	Z.
XLV.	,,	S.	20	Bolt Tail E.N.E. 6 miles	31	Z.

TABLE I. LIST OF STATIONS.

Explanation of abbreviations. S. surface. M. midwater. B. bottom. M.H. midnight haul (between 10 p.m. & 2 a.m.).

No. of haul.	Date.	Depth of capture.	Duration of haul in minutes.	Locality.	Total depth in fathoms.	Chart area.
XLVI.	2.vii.14	S.	20	Prawle Point N.E. 2 miles. M.H.	31	—
XLVII.	,,	S.	20	Prawle Point N.E. by N. 2 miles. M.H.	31	—
XLVIII.	,,	M.	20	Start Point N.E. 2 miles	27	—
XLIX.	,,	M.–B.	20	Start Point N.N.E. 2 miles. M.H.	32	—
L.	6.vii.14	B.	20	Rame N.N.W. 1 mile	20	T.
LI.	,,	B.	20	Rame N.N.W. 1½ miles	25	T.
LII.	,,	M.	20	Rame N.W. by N. 2½ miles	24	T.
LIII.	,,	B.	20	Cawsand Bay	∠10	T.U.
LIV.	9.vii.14	S.	20	Looe Is. W.N.W. ¼ mile	5	L.
LV.	,,	M.	20	Looe Is. N.W. 1 mile	10	M.
LVI.	,,	B.	20	Looe Is. N.N.W. 2 miles	23	M.
LVII.	,,	B.	20	Looe Is. N. 2 miles	23	M.
LVIII.	,,	M.	20	Rame Hd. E. by S. 2 miles	21	T.
LIX.	15.vii.14	M.	20	Rame E. 4 miles. M.H.	26	T.
LX.	,,	M.	20	Rame E. 4 miles. M.H.	26	T.
LXI.	16.vii.14	B.	20	Rame E. 6 miles	26	M.
LXII.	,,	B.	20	Rame E. 7 miles	27	M.
LXIII.	22.vii.14	B.	20	Cawsand Bay	∠10	T.U.
LXIV.	,,	B.	20	Between Penlee and Rame Bottom	10–12	T.
LXV.	,,	B.	20	Whitsands E.	∠10	T.U.
LXVI.	,,	M.	20	Whitsands W.	∠10	L.
LXVII.	,,	M.	20	Eddystone E. 1½ miles	32	S.

TABLE I. LIST OF STATIONS.

Explanation of abbreviations. S.=surface. M=midwater. B.=bottom. M.H.=midnight haul (between 10 p.m. & 2 a.m.).

No. of haul.	Date.	Depth of capture.	Duration of haul in minutes.	Locality.	Total depth in fathoms.	Chart area.
LXVIII.	22.vii.14	B.	20	Eddystone N.E. 4 miles	37	R.
LXIX.	,,	S.	20	Eddystone N.E. by N. 6 miles	38	Q.
LXX.	,,	M	20	Eddystone N.E. by N. 6 miles	38	Q.
LXXI.	,,	B.	20	Eddystone N. by E. 6 miles (Mosquito net)	38	Q.
LXXII.	,,	B.	20	Eddystone N. by E. 6 miles (Mosquito net)	38	Q.
LXXIII.	29.vii.14	M.	20	Eddystone S. $\frac{1}{4}$ mile	20	S.
LXXIV.	,,	M.	20	Eddystone S.E. by E. $\frac{1}{4}$ mile	20	S.
LXXV.	,,	B.	20	Eddystone N.E. by N. $\frac{1}{2}$ mile	25	S.
LXXVI.	,,	M.	20	Eddystone N. 2 miles	35	R.
LXXVII.	,,	B.	20	Eddystone N. by W. 2 miles	35	R.
LXXVIII.	,,	M.	20	Eddystone S.W. $4\frac{1}{2}$ miles	28	S.
LXXX.	,,	M.	20	Whitsand Bay E.	∠10	T.U.
LXXXI.	,,	M.	20	Whitsand Bay E.	∠10	T.U.
LXXXII.	,,	M.	20	Whitsand Bay W.	∠10	L.
LXXXIII.	,,	B.	20	Rame E. by S. $3\frac{1}{2}$ miles	23	T.
LXXXIV.	,,	B.	20	Rame E. by S. 4 miles (Mosquito net)	23	T.
LXXXV.	12.viii.14	M.	20	Rame E. by N. 5 miles	27	M.
LXXXVI.	,,	B.–M.	20	Rame E. by N. 4 miles	26	T.
LXXXVII.	4.ix.14	M.	30	Off Penlee	ca. 12	T.

Table II, showing the Number of Hauls made with the Young-fish Trawl in each month for each of the years from 1906 to 1914 in which investigations were carried on.

MONTHLY NUMBER OF HAULS.

	1906.	1907.	1908.	1909.	1913.	1914.	Total.
March . . .	—	2	—	—	—	—	2
April . . .	—	2	—	2	—	3	7
May . . .	8	—	4	5	—	13	30
June . . .	10	2	31	12	23	28	106
July . . .	4	4	10	9	29	38	94
August . . .	—	—	9	10	54	2	75
September . .	7	—	—	—	77	1	85
October . . .	1	—	—	—	13	—	14
November . .	—	—	—	—	9	—	9

CLUPEIDÆ.

As in the previous years the Clupeidæ show a very marked maximum frequency in May and the first half of June. A considerable number of specimens have been stained and the vertebræ counted. In all cases these have proved to be sprats, and there seems no doubt that the sprat constitutes by far the greater proportion of the specimens taken during the months in which the 1914 material was collected. This is rendered more probable by the fact that the abundance of black pigment in the neighbourhood of the anus, which Ehrenbaum considers to be one of the distinguishing characters of post-larval sprats, was observed in nearly all the specimens examined. Unfortunately in the present state of our knowledge of the early stages of the different species of Clupea, the detection of a few specimens of *C. harengus* or *C. pilchardus* amongst the large quantities of *C. sprattus* which are caught in the young-fish trawl is from a practical point of view impossible, the labour involved in staining and counting the vertebræ of so many specimens being altogether out of proportion to the value of the information which would be gained.

TABLE III.

Record of Clupea sp.

No. of haul.	Date.	Depth.	No.	Size in mm.
V.	29.iv.14	B.	74	7–16·5
VI.	,,	M.	13	5·6–11·5
VII.	,,	S.	62	6–22
VIII. (1)	8.v.14	M.	Very many	9·5–25
VIII. (2)	,,	M.	220	9·5–24
IX. (1)	15.v.14	M.	54	9–22·5
IX. (3)	,,	S.	5	12–16·5
IX. (5)	,,	B.	80	6–24
XI.	19.v.14	S.	1	16
XII.	,,	S.	460	6·2–20
XIII.	,,	M.	406	5·5–20
XIV.	25.v.14	M.	Very many	8–25
XV.	,,	S.	Many thousands	
XVI.	,,	S.	,, ,,	9–25
XVII.	3.vi.14	B.	218	6·7–18·5
XVIII.	,,	B.	415	6·1–18·5
XIX.	,,	M.	195	6–19·5
XX.	10.vi.14	S.–M.	Very many	10·5–28
XXII.	11.vi.14	M.–B.	,, ,,	
XXIII.	,,	B.	80	14–27
XXIV.	16.vi.14	B.	7	14·5–19·5
XXV.	,,	B.	9	12·3–18 ca.
XXVI.	,,	B.	7	9–17
XXVII.	,,	M.	34	11·6–20
XXIX.	17.vi.14	B.	5	14–24
XXXI.	,,	M.	5	11·5–23·5
XXXII.	,,	S.	65	11·5–25
XXXIV.	19.vi.14	M.	3	8·2–13
XXXV.	,,	M.	10	7·2–20·5
XXXVI.	24.vi.14	B.	10	7·7–14·5
XXXVII.	,,	B.	11	7·5–19
XXXVIII.	,,	M.	26	7–16
XXXIX.	,,	S.	10	7·5–20
XLII.	29.vi.14	B.	2	10–13
XLIII.	,,	B.	6	9–13
XLIV.	,,	M.	4	9·5–11·5
XLV.	,,	S.	1	9·5
XLIX.	2.vii.14	M.–B.	71	11·5–35·5

TABLE III. (*continued*).

No. of haul.	Date.	Depth.	No.	Size in mm.
L.	6.vii.14	B.	6	13–28 ca.
LI.	,,	B.	9	11·5–19
LII.	,,	M.	3	12–21
LIII.	,,	B.	1	19
LIV.	9.vii.14	S.	7	13·5–24
LV.	,,	M.	3	15–16·5
LVI.	,,	B.	2	17–19
LVII.	,,	B.	1	20
LVIII.	,,	M.	2	19·5–22
LIX.	15.vii.14	M.	30	13–26
LX.	,,	M.	35	13–29
LXI.	16.vii.14	B.	89	11–26
LXII.	,,	B.	4	12·5–17
LXVII.	22.vii.14	M.	7	5·7–15·5
LXVIII.	,,	B.	30	10–17
LXIX.	,,	S.	7	13–21
LXX.	,,	M.	2	9·5–14
LXXIII.	29.vii.14	M.	1	17
LXXV.	,,	B.	11	9·5–17
LXXVII.	,,	B.	2	10–10·5
LXXVIII.	,,	M.	1	21
LXXXIII.	,,	B.	1	19
LXXXIV.	,,	B.	2	21–23
LXXXVII.	4.ix.14	M.	2	20·5–22·3

SYNGNATHIDÆ.

Only six specimens belonging to this family are present in the material, the small number being due to the fact that most of the hauls were made at considerable distances from the shore. The four hauls in which they occurred were made between Penlee and Rame Head and in Whitsand Bay, the total depth of water being in all cases not greater than 15 fathoms.

TABLE IV.

RECORD OF SYNGNATHUS ROSTELLATUS.

No. of haul.	Date.	Depth.	No.	Size in mm.
XXIX.	17.vi.14	B.	1	26·5
LXIV.	22.vii.14	B.	1	17·5
LXXX.	29.vii.14	M.	2	23–30·5
LXXXI.	,,	M.	2	35–52

AMMODYTIDÆ.

All the specimens of Ammodytes appear to belong to the same species, which is probably *A. lanceolatus*, though as Clark (**1914**) points out, it is difficult to distinguish between the young stages of *A. lanceolatus* and *A. tobianus*. Table V. gives the records for 1914, whilst Table VI. gives the monthly totals and averages per haul for all the years 1906–1914 for which records exist. The average shows a gradual rise to a maximum in August and then a sudden drop (cf. Clark (**1914**), p. 340).

TABLE V.

Record of Ammodytes sp.

No. of haul.	Date.	Depth.	No.	Size in mm.
V.	29.iv.14	B.	5	10·5–29
VI.	,,	M.	1	20
VII.	,,	S.	1	22·6
IX.	15.v.14	B.	2	7, 17
XII.	19.v.14	S.	2	12·6, 19
XIII.	,,	M.	1	7
XIII. a	22.v.14		1	14
XIV.	25.v.14	M.	2	7·5, 8
XVI.	,,	S.	3	6–11·5
XVII.	3.vi.14	B.	10	9–18
XVIII.	,,	B.	14	5·6, 12·3–18
XXI.	11.vi.14	M.	1	10·6
XXII.	11.vi.14	M.–B.	1	7·5
XXVI.	16.vi.14	B.	4	8·5–10·5
XXVII.	,,	M.	1	8 ca.
XXX.	17.vi.14	M.	3	9–23
XXXI.	,,	M.	1	8 ca.
XXXII.	,,	S.	1	12·5
XXXIII.	19.vi.14	M.	1	20·5
XXXIV.	,,	M.	1	13
XXXV.	,,	M.	7	7·6–12·6
XXXVII.	24.vi.14	B.	4	6–15·5
XXXVIII.	,,	M.	5	5·5–15
XXXIX.	,,	S.	1	10
XLVI.	2.vii.14	S.	1	12·5
XLVIII.	,,	M.	2	9–13
L.	6.vii.14	B.	9	11–24

No. of haul.	Date.	Depth.	No.	Size in mm.
LI.	6.vii.14	B.	3	12·5–18·5
LII.	,,	M.	3	23 ca.
LIV.	9.vii.14	S.	1	18·5
LVI.	,,	B.	2	12–17·5
LVII.	,,	B.	1	12 ca.
LIX.	15.vii.14	M.	7	10–16
LX.	,,	M.	8	12–23·5
LXI.	16.vii.14	B.	5	13·7–30
LXII.	,,	B.	5	15–19·5
LXVI.	22.vii.14	M.	1	12
LXVII.	,,	M.	8	8–12·5
LXVIII.	,,	B.	16	7–14·8
LXIX.	,,	S.	3	9–13
LXXIII.	29.vii.14	M.	2	13–15
LXXIV.	,,	M.	1	12
LXXV.	,,	B.	13	6·5–15·8

TABLE VI.

AMMODYTES SP.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	1	1	8·5	0·5
April . . .	7	6	14	6·5–29	2
May . . .	30	11	32	6–29	1·07
June . . .	106	49	247	5·5–104	2·3
July . . .	94	52	420	5–30	4·5
August . . .	75	46	506	4·5–25	6·7
September . .	85	12	14	5·5–24	0·16
October . . .	14	0	0		
November . .	9	0	0		

GADIDÆ.

Gadus pollachius L. *G. merlangus* L. *G. minutus* O. F. Müller.
G. luscus L.

Table VII. gives the records of the above species for 1914, whilst Tables VIII. to XI. show the monthly totals and averages of all the records from 1906–1914. The few specimens of *G. pollachius* taken in 1914 were nearly all taken in April and the first half of May. The maximum frequency for the whole period is in March and April. For the whiting

(*G. merlangus*) the maximum is in May, whilst in June specimens of the sizes captured by the young-fish trawl are still fairly numerous. May also shows a distinct maximum for *G. luscus* and *G. minutus*. Specimens of all these gadoids are very infrequent in hauls taken after June.

TABLE VII.

Record of Gadus sp.

No. of haul.	Date.	Depth.	G. pollachius. No.	G. pollachius. Size in mm.	G. merlangus. No.	G. merlangus. Size in mm.	G. luscus. No.	G. luscus. Size in mm.	G. minutus. No.	G. minutus. Size in mm.
V.	29.iv.14	B.	2	6–16·5	2	6–6·5	—	—	6	7–14
VI.	,,	M.	—	—	—	—	—	—	2	7·5–10·5
VII.	,,	S.	7	5·5–13	—	—	—	—	—	—
VIII.(2)	8. v.14	M.	—	—	1	7	—	—	1	8·5
IX.(1)	15.v.14	M.	4	8–10	103	5·5–11·5	—	—	—	—
IX.(3)	,,	S.	6	7·5–9·5	5	8·5–10·2	—	—		—
IX.(5)	,,	B.	—	—	211	6·5–15	4	6–8	1	7·5
X.	19.v.14	M.	—	—	10	6–16	—	—	—	—
XI.	,,	S.	3	5·5–9	1	6·5	—	—	2	7–9
XII.	,,	S.	3	9·6–13	4	7–12	5	6–9·8	16	5·4–12·3
XIII.	,,	M.	—	—	8	5·5–8·3	7	5·6–6·2	158	5·5–15
XIV.	25.v.14	M.	—	—	21	7·2–14	11	6·5–16	34	6·5–16
XV.	,,	S	—	—	4	8–13	2	8–8·5	23	6·7–14
XVI.	,,	S.	—	—	14	5·5–18	6	7·8–12·7	89	6–17
XVII.	3.vi.14	B.	—	—	31	6·3–9·5	—	—	4	5·3–8·5
XVIII.	,,	B.	—	—	24	6·5–11	—	—	—	—
XIX.	,,	M.	—	—	6	7–13	—	—	—	—
XX.	10.vi.14	S.–M.	—	—	—	—	1	9·3	—	—
XXI.	11.vi.14	M.	—	—	3	8·5–9·5	1	9·5	—	—
XXII.	,,	M.–B.	—	—	1	8·5	—	—	3	6·5–17·7
XXIII.	,,	B.	—	—	—	—	1	7	8	7·6–10
XXV.	16.vi.14	B.	—	—	1	6	—	—	—	—
XXVI.	,,	B.	—	—	4	6·2–16	—	—	—	—
XXVIII.	,,	B.	—	—	1	11	—		—	—
XXX.	17.vi.14	M.	1	5·6	2	8–13·5	—	—	—	—
XXXII.	,,	S.	—	—	4	9–18	—	—	—	—
XXXVI.	24.vi.14	B.	—	—	1	14	—	—	—	—
XXXVII.	,,	B.	—	—	—	—	—	—	1	18
XXXVIII.	,,	M.	—	—	2	11–11·5	2	5·3–5·5	—	—
XLI.	26.vi.14	B.	—	—	—	—	—	—	25	11–28
XLIV.	29.vi.14	M.	—	—	1	19	—	—	—	—
XLVI.	2.vii.14	S.	—	—	2	25–31	1	10·2	—	—
LV.	9.vii.14	M.	—	—	1	7·5	—	—	—	—
LXVII.	22.vii.14	M.	1	7.2	—	—	—	—	—	—
LXVIII.	,,	B.	—	—	—	—	—	—	1	8·6
LXXVII.	29.vii.14	B.	—	—	—	—	—	—	1	12·4

TABLE VIII.

GADUS POLLACHIUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	2	23	3–5	11·5
April . . .	7	4	46	3·5–16·5	6·6
May . . .	30	8	21	5–22	0·7
June . .	106	5	20	5·6–42	0·2
July . . .	94	2	2	6–7·2	0·01

TABLE IX.

GADUS MERLANGUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	1	2	3–4	1
April . .	7	5	51	3·5–10	7·3
May . . .	30	24	1009	4–18	33·6
June . . .	106	66	584	3–40	5·5
July . . .	94	10	22	6–52·5	0·2
August . . .	75	1	1	62	0·01

TABLE X.

GADUS LUSCUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	0	-	—	
April .	7	3	3	5·5–7·5	0·4
May .	30	8	11	5–16	1·5
June . .	106	13	15	4–9·5	0·14
July . . .	94	1	1	10·2	0·01
August . . .	75	– –	.	– –	– –
September . .	85	5	5	4–8	0·06
October . .	14	4	5	3·4–4·9	0·36
November .	9	1	1	3·4	0·1

TABLE XI.

Gadus minutus.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	2	14	4·5–7	7
April . . .	7	3	11	7–18	1·6
May . . .	30	16	405	4–17	13·5
June . . .	106	16	116	5–48	1·1
July . . .	94	5	5	8·6–54	0·05

GADIDÆ.

Molva molva L.

During the period 1906–13, eight post-larval specimens of *Molva molva* were taken in May and twenty-two in June.

TABLE XII.

Record of Molva molva L.

No. of haul.	Date.	Depth.	No.	Size in mm.
XII.	19.v.14	S.	1	10·3
XVI.	25.v.14	S.	2	8·6–11
XVII.	3.vi.14	B.	1	8
XXII.	11.vi.14	M.	2	8·5–10·5
XXVIII.	16.vi.14	B.	1	8·6
XXXVIII.	24.vi.14	M.	1	12·5
XLIV.	29.vi.14	M.	1	10 ca.
L.	6.vii.14	B.	1	20 ca.

GADIDÆ.

Raniceps raninus L.

The single specimen of the lesser forkbeard taken in 1914 was obtained at the end of July. Previous records of post-larvæ of the species at Plymouth are all due to Clark who obtained eight specimens in August and September, 1913.

TABLE XIII.

Record of Raniceps raninus L.

No. of haul.	Date.	Depth.	No.	Size in mm.
LXXIII.	29.vii.14	M.	1	8

GADIDÆ.

Onos mustelus L.

All the post-larval rocklings have been identified as *O. mustelus*. The differences between the species are not, however, very well defined, and it is possible that a few of the specimens may belong to *O. tricirratus* Bl. or to *O. cimbrius* L.

TABLE XIV.

Record of Onos mustelus L.

No. of haul.	Date.	Depth.	No.	Size in mm.
V.	29.iv.14	B.	2	4·8–8·5
VII.	,,	S.	6	4·5–6·5
IX. (1)	15.v.14	M.	3	6·6–7·3
IX. (3)	,,	S.	1	6·5
IX. (5)	,,	B.	1	6
X.	19.v.14	M.	5	5·4–10
XII.	,,	S.	3	6·1–11
XIII.	,,	M.	5	5–8·5
XIV.	25.v.14	M.	7	5–16
XV.	,,	S.	5	6–15·6
XVI.	,,	S.	14	6·5–15·5
XVIII.	3.vi.14	B.	2	7–7·5
XIX.	,,	M.	1	6·8
XXI.	11.vi.14	M.	1	31
XXII.	,,	M.–B.	1	28·5
XXIV.	16.vi.14	B.	3	7–25
XXXI.	17.vi.14	M.	2	5·2
XXXII.	,,	S.	2	5·5
XXXVIII.	24.vi.14	M.	3	5·3–6·5
XXXIX.	,,	S.	1	6·5
XLVI.	2.vii.14	S.	2	6·3–8·5
XLVIII.	,,	M.	1	7
XLIX.	,,	M.–B.	1	9·8
LIX.	15.vii.14	M.	2	8·8–31
LX.	,,	M.	4	12–32
LXXIII.	29.vii.14	M.	1	7·5

TABLE XV.

ONOS MUSTELUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
April . . .	7	3	9	4·5–8·5	1·3
May	30	10	45	5–16	1·5
June . . .	106	29	46	2·7–31	0·4
July	94	14	19	4·2–32	0·2
August . . .	75	1	1	4·9	0·01
September . . .	85	1	1	8	0·01

SERRANIDÆ.

Roccus labrax L. (=*Labrax lupus* Cuv.)

One specimen of a larval bass 6 mm. long was obtained in Haul IX. (1), a midwater haul made in the west part of Bigbury Bay on May 15th, 1914. It is well represented by Raffaele's figure (**1888** Tav. IV. Fig. 2), which is reproduced by Ehrenbaum in Nordisches Plankton (**1905**) as Fig. 7.d.

LABRIDÆ.

Labrus bergylta Asc. *Labrus mixtus* L. *Ctenolabrus rupestris* L.

Young stages of wrasse belonging to three different species occur in the material, but there is some slight doubt as to their correct specific determination. The most numerous of the forms is the one in which the body and the greater part of the tail is covered with many black stellate chromatophores, which, however, cease more or less abruptly behind the anal fin, leaving the hinder end of the tail unpigmented. This form has been figured by Danois (**1913**, p. 155) and there seems no reason to doubt that he has identified it correctly as *L. bergylta*. Holt's figure (**1899**, Pl. V. Fig. 49) is probably the same species, Ehrenbaum (**1905**, p. 7) having already pointed out that it certainly is not *Ctenolabrus rupestris* as Holt has named it. The just hatched larva of *L. bergylta* was described by Matthews (**1887**), and it is not improbable that the larva described by Hefford (**1910**, Pl. I. Figs. 8 and 8a) as *L. mixtus* also belongs here. In the present records, as well as in those by Clark (**1914**), all the specimens in which the body is deeply pigmented, but the hinder portion of the tail is quite free from pigment, have been regarded as *Labrus bergylta*.

A second form is *Ctenolabrus rupestris*. This is well figured by Ehrenbaum (**1905**, p. 8). The body is free from pigment excepting for a large post-anal black chromatophore on the body at the hinder end of the anal fin, and one or two chromatophores at the root of the caudal fin. I see no reason to question Ehrenbaum's identification, which is also accepted by Clark.

The third form, of which I give an illustration in Fig. 1, kindly made for me by Mr. E. Ford, has occurred not infrequently in the 1914 material. The distribution of the chromatophores is very constant and characteristic. On the dorsal edge of the body, at the base of the dorsal fin, there are on each side five large black chromatophores which remain in specimens preserved in formalin. One of these, the smallest, lies beneath the anterior end of the dorsal fin, followed by two large ones near the middle of the fin, and finally a pair close together near its hinder end. On the post-anal, ventral edge of the body there is a large chromatophore a little way behind the anus, and two more near the posterior end of the anal fin. A single black chromatophore can generally be seen at the base of the caudal fin. In the anterior part of the fish there are two or three large chromatophores on the top of the head, a row of small ones on the mandible, two or three on the ventral edge of the abdomen, and one fairly large one immediately in front of the anus. A line of pigment extends along the dorsal side of the abdominal cavity, extending nearly to the anus. The number of vertebræ is 38 or 39, rays of dorsal fin 30 or 31, of anal fin 14 or 15. These numerical characters agree completely with those given by Day for *Labrus mixtus*, and amongst the British Labridæ the only other species in which the number of vertebræ is so high is *Labrus bergylta*, the young stage of which seems to be satisfactorily known. I have little hesitation therefore in regarding *Labrus mixtus* as the proper name to give to the form we are considering. If that be so the larva described by Hefford (**1910**) is probably *L. bergylta* and not *L. mixtus* as he was inclined to think.

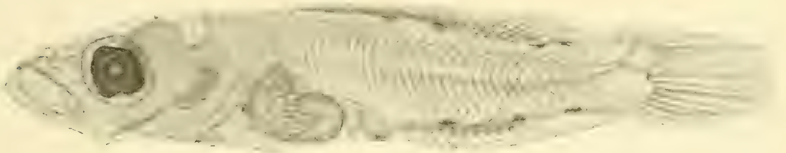


FIG. 1.—*Labrus mixtus* L. Length 10 mm. July 2nd, 1914.

Post-larval stages of *Labrus bergylta* are most numerous in June and July, a few were taken in May and August, whilst in September they practically disappear from the young-fish trawl material. *Ctenolabrus rupestris* was most abundant in July. In 1914, the only year for which the species is recorded, *Labrus mixtus* was distinctly earlier in appearance than *C. rupestris* and was most abundant in June.

TABLE XVI.

Record of Labrus sp.

No. of haul.	Date.	Depth.	Labrus bergylta. No.	Labrus bergylta. Size in mm.	Labrus mixtus. No.	Labrus mixtus. Size in mm	Ctenolabrus rupestris. No.	Ctenolabrus rupestris. Size in mm.
IX.(1)	15.v.14	M.	4	5·8–7·3	—	—	—	—
X.	19.v.14	M.	1	6·5	—	—	—	—
XII.	,,	S.	—	—	1	6·6	—	—
XIII.	,,	M.	1	6	—	—	—	—
XIV.	25.v.14	M.	3	5·6–6·3	2	7, 7·2	—	—
XV.	,,	S.	4	5·2–6·5	—	—	—	—
XVI.	,,	S.	—	—	1	8·3	—	—
XVII.	3.vi.14	B.	13	5·3–7·5	1	6·5	—	—
XVIII.	,,	B.	6	6–7	—	—	—	—
XIX.	,,	M.	1	6·5	—	—	—	—
XX.	10.vi.14	S.–M.	—	—	2	8–8·5	—	—
XXII.	11.vi.14	M.–B.	—	—	1	9·2	—	—
XXIII.	,,	B.	—	—	1	8·5	—	—
XXIV.	16.vi.14	B.	1	5·5	—	—	—	—
XXV.	,,	B.	1	5.5	1	6	—	—
XXVI.	,,	B.	1	6	2	6·7–8	—	—
XXVII.	,,	M.	2	6–7·5	—	—	—	—
XXIX.	17.vi.14	B.	3	6·3–7	—	—	—	—
XXX.	,,	M.	1	6·5	1	6·5	—	—
XXXIV.	19.vi.14	M.	1	7·4	—	—	—	—
XXXVI.	24.vi.14	B.	—	—	1	7	—	—
XXXVII.	,,	B.	—	—	—	—	1	6
XXXVIII.	,,	M.	—	—	—	—	2	7·3–8
XLIII.	29.vi.14	B.	—	—	—	—	1	8·5
XLVI.	2.vii.14	S.	1	8·3	2	9–10	1	9
XLVII.	,,	S.	—	—	2	6·2–10	—	—
XLVIII.	,,	M.	1	5·7	—	—	—	—
XLIX.	,,	M.–B.	2	4·5–5·7	1	8·5	—	—
L.	6.vii.14	B.	2	5·5–6·5	—	—	—	—
LI.	,,	B.	11	4·2–5·6	—	—	—	—
LII.	,,	M.	1	5·3	—	—	—	—
LIV.	9.vii.14	S.	10	5·7–6·5	—	—	—	—
LV.	,,	M.	12	4–5·7	—	—	—	—
LVI.	,,	B.	1	5 ca.	—	—	—	—
LIX.	15.vii.14	M.	2	7–8	—	—	—	—
LXI.	16.vii.14	B.	1	7	—	—	—	—
LXII.	,,	B.	1	7	—	—	—	—
LXIII.	22.vii.14	B.	1	6·6	—	—	—	—
LXIV.	,,	B.	1	8	—	—	—	—
LXVIII.	,,	B.	—	—	2	7–7·7	—	—
LXIX.	,,	S.	—	—	—	—	1	8
LXXIII.	29.vii.14	M.	1	6	—	—	1	8·6
LXXIV.	,,	M.	—	—	—	—	1	9·5
LXXV.	,,	B.	—	—	—	—	1	9·6
LXXX.	,,	M.	1	8	—	—	1	8·5
LXXXV.	12.viii.14	M.	1	7·5	—	—	—	—
LXXXVI.	,,	B.–M.	3	9·5–10	—	—	1	9

TABLE XVII.

LABRUS BERGYLTA.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
May	30	8	26	4·5–7·5	0·87
June	106	42	240	3·25–24	2·2
July	94	49	348	3–20	3·7
August	75	19	29	3–10	0·38
September	85	1	1	4·5	0·01

TABLE XVIII.

LABRUS MIXTUS.

(1914 only.)

Month.	Total number of hauls 1914 only.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
May	13	3	4	6·6–8·3	0·31
June	28	8	10	6·5–9·2	0·36
July	38	3	7	7–10	0·18

TABLE XIX.

CTENOLABRUS RUPESTRIS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
June	106	14	39	3·8–9·8	0·37
July	94	30	131	4–10	1·4
August	75	8	13	5·5–9	0·17

CARANGIDÆ.

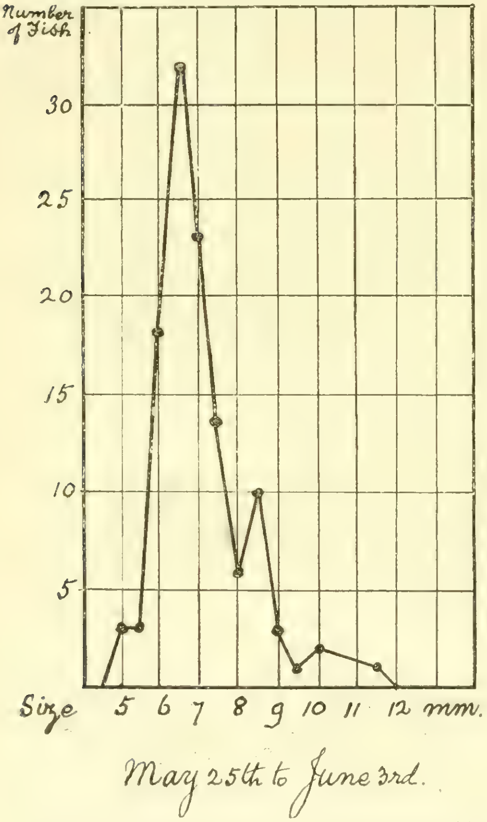
Caranx trachurus L.

Only one specimen of the scad or horse mackerel is recorded amongst the 1914 material. This was 23·5 mm. long, with most of the adult characters developed, and was taken in Haul LXXXVII. at midwater off Penlee Point on September 4th. The previous records given by Clark (**1914**, p. 348) are all for July, August and September.

SCOMBRIDÆ.

Scomber scomber L.

Perhaps the most interesting feature in the material collected with the young-fish trawl in 1914 is the abundance of young stages of the mackerel, which were far more numerous than in any of the previous years for which records are available, though a number of specimens were taken by Hefford (see Clark, **1914**, p. 349) in June, 1906, and June, 1908. These young stages were first taken on May 25th, when 22, 29 and 32 specimens were captured respectively in three successive hauls. The numbers were still considerable in the hauls on June 3rd. After that date they became less, but the young fish remained in the catches throughout June, whilst isolated specimens were captured in July.



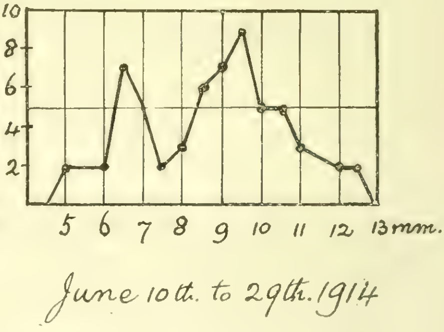


FIG. 2.—Frequency curve of young mackerel from Hauls XIV.–XIX., caught on May 25th and June 3rd, 1914.

FIG. 3.—Frequency curve of young mackerel from Hauls XX.–XLV., caught June 10th to 29th, 1914.

The individual fishes were measured, and the results to the nearest

·5 mm. are recorded in Table XX. Figs. 2 and 3 show in graphic form the length frequencies at each successive half-millimetre for two groups of hauls, the first group comprising XIV.–XIX., taken on May 25th and June 3rd, the second group comprising 16 hauls in which specimens occurred from Haul XX. to Haul XLV., taken between June 10th and 29th. The first group (Fig. 2) shows a definite mode at 6·5 mm. and the arithmetic mean is 7·15 mm. The second group (Fig. 3) has two modes, one at 6·5 mm. and another at 9·5 mm., whilst the arithmetic mean is 8·8 mm. It is probable that the mode at 9·5 in the second group (Fig. 3) is due to the group of fish found in the earlier hauls and represented in Fig. 2, which then showed a mode at 6·5 mm. This would indicate a growth of 3 mm. in three weeks. If this interpretation be correct then the other mode in Fig. 3, that at 6·5 mm., would be most easily explained

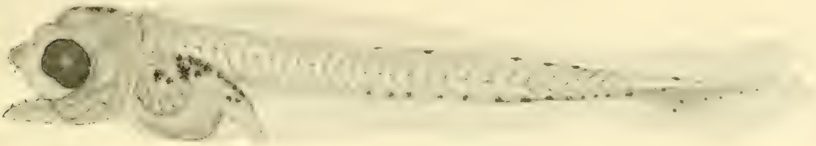


FIG. 4.—*Scomber scomber* L. Length 6 mm. May 25th, 1914.

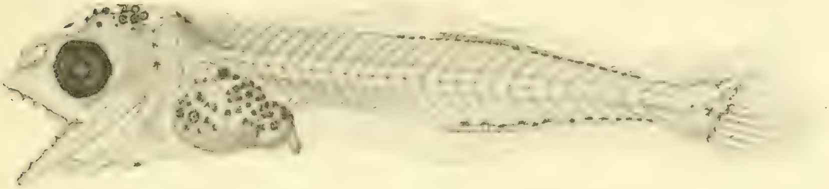


FIG. 5.—*Scomber scomber* L. Length 9 mm. May 25th, 1914.

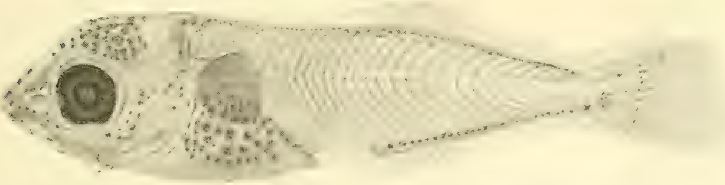


FIG. 6.—*Scomber scomber* L. Length 11·5 mm. May 25th, 1914.

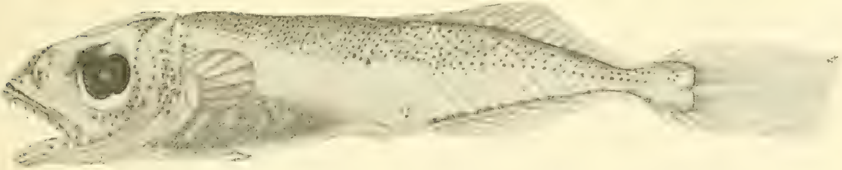


FIG. 7.—*Scomber scomber* L. Length 16 mm. ca. July 22nd, 1914.

as being due to the offspring of a second shoal of spawning fish appearing some three weeks later than the one whose offspring are represented in Fig. 2. A more detailed analysis of the figures by taking five groups of hauls instead of two, namely, (1) XIV., XV., XVI., (2) XVII., XVIII., XIX., (3) XX., XXI.. XXII., XXIII., (4) XXIV.–XXXVIII., (5) XLIII., XLIV., XLV., and noting that the fifth group comprises hauls taken more to the eastward, that is in the direction of the general Channel drift, than the hauls of groups (1) and (2) confirms the view just expressed, though I have not thought it necessary to reproduce the five curves here, the numbers of fish in each group being rather small.

In Figs. 4–7 are given four drawings made by Mr. E. Ford, representing four different stages in the growth of these young mackerel. In these drawings the characteristic distribution of the black pigment, the larval teeth, and the other characters by means of which the species can be distinguished are well shown.

TABLE XX.

Record of *Scomber scomber*.*

No. of haul.	Date.	Depth.	No.	Sizes in mm.
XIV.	25.v.14	M.	22	2 at 5, 1 at 5·5, 7 at 6, 6 at 6·5, 3 at 7, 1 at 7·5, 1 at 8, 1 at 8·5.
XV.	25.v.14	S.	29	1 at 5·5, 2 at 6, 8 at 6·5, 5 at 7, 4 at 7·5, 2 at 8, 4 at 8·5, 2 at 9, 1 at 10.
XVI.	25.v.14	S.	32	1 at 5, 7 at 6, 8 at 6·5, 5 at 7, 3 at 7·5, 1 at 8, 4 at 8·5, 1 at 9, 1 at 10, 1 at 11·5.
XVII.	3.vi.14	B.	21	1 at 5·5, 1 at 6, 8 at 6·5, 6 at 7, 3 at 7·5, 2 at 8.
XVIII.	3.vi.14	B.	10	1 at 6, 3 at 6·5, 3 at 7, 2 at 7·5, 1 at 9·5.
XIX.	3.vi.14	M.	3	1 at 7, 1 at 7·5, 1 at 8·5.
XX.	10.vi.14	S.–M.	3	1 at 7, 1 at 8, 1 at 12·5.
XXI.	11.vi.14	M.	3	1 at 8·5, 1 at 9, 1 at 10·5.
XXII.	11.vi.14	M.–B.	4	1 at 7·5, 2 at 11, 1 at 12.
XXIII.	11.vi.14	B.	4	1 at 9, 2 at 10·5, 1 at 11.
XXIV.	16.vi.14	B.	1	1 at 6·5.
XXVI.	16.vi.14	B.	2	1 at 8·5, 1 at 9·5.
XXVII.	16.vi.14	M.	7	1 at 5, 1 at 6, 2 at 9, 2 at 9·5, 1 at 10.
XXXI.	17.vi.14	M.	2	1 at 5, 1 at 8·5.
XXXII.	17.vi.14	S.	2	1 at 8, 1 at 9.

* Measurements to the nearest ·5 mm.

TABLE XX. (*continued*).

No. of haul.	Date.	Depth.	No.	Sizes in mm.
XXXIII.	19.vi.14	M.	1	1 at 12·5.
XXXIV.	19.vi.14	M.	1	1 at 6·5.
XXXVI.	24.vi.14	B.	1	1 at 7.
XXXVII.	24.vi.14	B.	1	1 at 7.
XXXVIII.	24.vi.14	M.	11	1 at 6, 4 at 6·5, 2 at 7, 1 at 7·5, 1 at 8, 1 at 8·5, 1 at 9·5.
XLIII.	29.vi.14	B.	2	1 at 8.5, 1 at 9·5.
XLIV.	29.vi.14	M.	3	1 at 6·5, 2 at 9·5.
XLV.	29.vi.14	S.	12	1 at 8·5, 2 at 9, 2 at 9.5, 4 at 10, 2 at 10·5, 1 at 12.
LX.	15.vii.14	M.	1	1 at 9·5.
LXVIII.	22.vii.14	B.	1	1 at 16.
LXIX.	22.vii.14	S.	1	1 at 8·5.

ZEIDÆ.

Zeus faber L.

One specimen only, 12 mm. long, was taken, this being found in Haul LXXXIV., a bottom haul made on July 29th, 1914. For 1913 Clark (**1914**) has recorded a number of specimens in August and September.

PLEURONECTIDÆ.

Pleuronectes limanda L.

Post-larval dates are exceptionally well represented in the 1914 material. Already at the end of April when the collection began 29 and 37 specimens were obtained in one haul. The maximum abundance was reached in May, and in three hauls taken off the Eddystone on May 25th, 290, 276, and 508 individuals were captured. It is worth noting that these three hauls were taken during the dark hours of the night, between 10.25 p.m. and midnight. During June the numbers obtained fell off rapidly and after the 2nd July no more specimens were obtained. During June also the most prolific hauls were made at night. The details of the captures for 1914 are shown in Table XXI., whilst Table XXII. gives monthly summaries of the hauls made during the period 1906–14.

Pleuronectes microcephalus Donov.

Although no young merry-soles were taken until May 15th the captures reached a maximum before the end of that month, falling off during

June and July, when chiefly the larger sizes were taken. The figures for 1914 are given in Table XXI., and the monthly summaries for 1906–14 in Table XXIII.

The species is more abundant in hauls taken beyond the 20-fathom line. In Table XXIII. this is shown by the figures given for the month of May. The average number of individuals per haul for all the hauls is 6·6, whilst the average for the hauls at and beyond the 20-fathom line is 12·2.

TABLE XXI.

Record of Pleuronectes sp.

No. of Haul.	Date.	Depth.	P. limanda. No.	P. limanda. Size in mm.	P. microcephalus. No.	P. microcephalus. Size in mm.
V.	29.iv.14	B.	36	5·5–11·5	—	—
VI.	,,	M.	29	4·5–9·2	—	—
VII.	,,	S.	6	5·5–10·5	—	—
VIII.(2)	,,	M.	3	6·2–8·5	—	—
IX.(5)	15.v.14	B.	23	5–12·6	3	9·5–11·2
X.	19.v.14	M.	5	8·5–14·3	37	5–11
XI.	,,	S.	8	9–13·8	22	6·5–10·5
XII.	,,	S.	35	4–14·8	21	6·8–10·6
XIII.	,,	M.	70	4·7–12·0	55	6–15
XIII.a	22.v.14		46	6·5–13	—	—
XIV.	25.v.14	M.	290	5·7–15	25	7–14·7
XV.	,,	S.	276	5·5–12·5	7	9·6–13·5
XVI.	,,	S.	508	5–12·6	12	7·5–14·5
XVII.	3.vi.14	B.	45	6·5–11·5	5	7–9
XVIII.	,,	B.	9	6–8	8	5·2–7·5
XIX.	,,	M.	4	6·7–8	1	6
XX.	10.vi.14	S.–M.	22	8·2–14·5	3	9·5–16
XXI.	11.vi.14	M.	14	8–14·2	3	10·6–14
XXII.	,,	M.–B.	31	8·5–17	11	10–15·6
XXIII.	,,	B.	32	9–15·6	22	9–14
XXVI.	16.vi.14	B.	3	10·5–11·6	—	—
XXVII.	,,	M.	1	10·5	—	—
XXVIII.	,,	B.	1	12·5	—	—
XXXI.	17.vi.14	M.	2	8·7–11	—	—
XXXII.	,,	S.	—	—	1	7
XXXVII.	24.vi.14	B.	1	10·2	3	8–12
XLIII.	29.vi.14	B.	1	10·5	—	—
XLVI.	2.vii.14	S.	8	6·5–17·3	2	12·4–12·7
XLVII.	,,	S.	1	8·5	3	11·5–15·2

TABLE XXI. (*continued*).

No of Haul.	Date.	Depth.	P. limanda.		P. microcephalus.	
			No.	Size in mm.	No.	Size in mm.
XLVIII.	2.vii.14	M.	3	15·5–16	3	9–18·5
XLIX.	,,	M.–B.	2	15·5–16·6	—	—
LVI.	9.vii.14	B.	—	—	2	9·2–11·5
LVII.	,,	B.	—	—	2	9–9·5
LXVIII.	22.vii.14	B.	—	—	1	8
LXXVIII.	29.vii.14	M.	—	—	1	8

Pleuronectes flesus L. occurred in the following hauls:—V. 1 spec. 7 mm., VII. 3 specs. 6·5–8·5 mm., VIII. (1) 2 specs. 8–8·5 mm., VIII. (2) 2 specs. 8–8·5 mm., IX. (1) 1 spec. 9 mm., IX. (2) 33 specs. 5·5–10·5 mm.

TABLE XXII.

PLEURONECTES LIMANDA.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
April	7	5	86	4·5–11·5	12·3
May	30	20	1371	4–15	45·7
June	106	28	199	1·59–17	1·9
July	94	5	17	6·5–42	0·18

TABLE XXIII.

PLEURONECTES MICROCEPHALUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
March	2	1	1	6	0·5
April	7	0	0	—	—
May	30	10	199	5–15	6·6
*May**	*16*	*9*	*196*	*5–15*	*12·2*
June	106	30	129	5–16	1·2
July	94	10	18	7–18·5	0·19

* Hauls where total depth of water is 20 fathoms and over.

PLEURONECTIDÆ.

Sub.-fam. BOTHINÆ.

Arnoglossus sp.

The records for 1914 are given in Table XXIV. By far the greater number of specimens taken belong certainly to the species *Arnoglossus laterna.* There were a certain number of doubtful cases, but in no instance was I able to feel sure that the specimen should be attributed to *A. Thori* or *A. imperialis.*

The monthly summaries for the whole period 1906–14 given in Table XXV. show a maximum frequency in September with an average of 8·3 per haul. The average for August 6·8 is also high. It may be noted, however, that the post-larval Arnoglossus seems to have been more abundant in June, 1914, than it was in that month of previous years, the average for the month being 8·4 in 1914, whilst for the whole period it is only 2·3.

TABLE XXIV.

RECORD OF ARNOGLOSSUS SP.

No. of haul.	Date.	Depth.	No.	Size in mm.
XI.	19.v.14	S.	1	5·5 ca.
XIII.	,,	M.	1	5·6
XIV.	25.v.14	M.	5	5–8·3
XV.	,,	S.	7	6·5–8·3
XVI.	,,	S.	12	5·6–7·6
XVII.	3.vi.14	B.	11	5·5–7·5
XVIII.	,,	B.	18	4–8
XIX.	,,	M.	1	5·2
XX.	10.vi.14	S.–M.	17	9·5–11·7
XXI.	11.vi.14	M.	28	6·5–11·2
XXII.	,,	M.–B.	27	7–11
XXIII.	,,	B.	47	7·5–12·3
XXV.	16.vi.14	B.	1	7
XXVI.	,,	B.	10	3·5–7·3
XXVII.	,,	M.	3	6·3–9
XXX.	17.vi.14	M.	2	6·5
XXXI.	,,	M.	18	5·5–10
XXXII.	,,	S.	3	6–10 ca.
XXXIV.	19.vi.14	M.	5	6·4–10·8

TABLE XXIV. (*continued*).

No. of haul.	Date.	Depth.	No.	Size in mm.
XXXV.	19.vi.14	M.	3	6·5–12·3
XXXVI.	24.vi.14	B.	6	6·5–14
XXXVII.	,,	B.	1	10·5
XXXVIII.	,,	M.	10	—
XLII.	29.vi.14	B.	2	9–14·5
XLIII.	,,	B.	14	8·5–18·5
XLIV.	,,	M.	5	5–17·5
XLV.	,,	S.	3	6·5–9
XLVI.	2.vii.14	S.	4	8·2–13
XLVII.	,,	S.	1	15·5
XLVIII.	,,	M.	4	11–18
XLIX.	,,	M.–B.	3	6·5–15
L.	6.vii.14	B.	1	18·3
LI.	,,	B.	4	4·5–18·5
LII.	,,	M.	1	17
LV.	9.vii.14	M.	2	12·5–16·5
LVI.	,,	B.	6	11–17·5
LVII.	,,	B.	1	13
LVIII.	,,	M.	1	19·5
LIX.	15.vii.14	M.	29	13·5–22
LX.	,,	M.	11	13·4–20·3
LXI.	16.vii.14	B.	2	13–16
LXII.	,,	B.	6	15–21 ca.
LXIII.	22.vii.14	B.	1	7·2
LXVII.	,,	M.	7	7·2–19·5
LXVIII.	,,	B.	5	7–20·5
LXX.	,,	M.	2	18·7–21·2
LXXIII.	29.vii.14	M.	10	6·3–20·5
LXXV.	,,	B.	4	8·2–20·5
LXXVI.	,,	M.	5	17–20·5
LXXVII.	,,	B.	1	20
LXXVIII.	,,	M.	14	10–23·5
LXXXIII.	,,	B.	3	9·5–20·5
LXXXV.	12.viii.14	M.	2	24·5–25·6

TABLE XXV.

ARNOGLOSSUS SP.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
May	30	5	26	5–8·3	0·87
June	106	30	249	3·5–18·5	2·3
[*June, 1914* . .	*28*	*22*	*235*	*3·5–18·5*	*8·4*]
July	94	41	232	3·5–23·5	2·5
August . . .	75	47	507	3–28·5	6·8
September . . .	85	62	708	4–31	8·3
October . . .	14	2	2	7	0·14

Sub-fam. RHOMBINÆ.

Rhombus maximus Will. *R. laevis* Rond.

Seven specimens of *R. laevis* were taken in 1914 between May and August, and one specimen of *R. maximus* in July. These records support the conclusion reached by Clark that the spawning season of the brill is earlier than that of the turbot.

TABLE XXVI.

RECORD OF RHOMBUS SP.

No. of haul.	Date.	Depth.	R. maximus. No.	R. maximus. Size in mm.	R. laevis. No.	R. laevis. Size in mm.
XIV.	25.v.14	M.	—	—	2	9·8–11·5
XV.	25.v.14	S.	—	—	2	6·8,6·8
LXX.	22.vii.14	M.	—	—	1	6·2
LXXVI.	29.vii.14	M.	2	7·7–8·5	—	—
LXXVIII.	29.vii.14	M.	—	—	1	7
LXXXV.	12.viii.14	M.	—	—	1	13

Scophthalmus norvegicus Gthr.

The records for 1914 (Table XXVII.) give a distinct maximum of the post-larval stages in May. The numbers remain fairly large until June 11th, after which only a few specimens were taken. This would indicate that the maximum spawning season is a little earlier than Clark (**1914**) suggests, being probably in April. The hauls containing the largest number of individuals were made south of the Eddystone, where the depths were from 37–39 fathoms. The monthly summary for the period 1906–14 shows an average number of 14·6 individuals per haul for May, and of 5·4 for June (Table XXVIII.).

TABLE XXVII.

RECORD OF SCOPHTHALMUS NORVEGICUS.

No. of haul.	Date.	Depth.	No.	Size in mm.
X.	19.v.14	M.	69	4·2–11
XI.	,,	S.	44	4–12
XII.	,,	S.	68	4·5–12
XIII.	,,	M.	84	4–11·7
XIII.a	22.v.14	—	2	6–6·6
XIV.	25.v.14	M.	5	5·5–10
XV.	,,	S.	1	9·5
XVI.	,,	S.	6	6·5–10·5
XVII.	3.vi.14	B.	45	4·0–8·0
XVIII.	,,	B.	31	4·5–8
XIX.	,,	M.	1	7
XX.	10.vi.14	S.–M.	5	6–8
XXI.	11.vi.14	M.	11	5·5–8·5
XXII.	,,	M.–B.	16	6–8·7
XXIII.	,,	B.	27	6–8·7
XXVI.	16.vi.14	B.	1	5·5
XXX.	17.vi.14	M.	1	6
XLVI.	2.vii.14	S.	1	9·7
LVI.	9.vii.14	B.	1	7·3
LIX.	15.vii.14	M.	1	6
LXVIII.	22.vii.14	B.	1	7·2

TABLE XXVIII.

SCOPHTHALMUS NORVEGICUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
May	30	14	438	4–12	14·6
June	106	39	576	3·5–12·2	5·4
July	94	16	33	4–11	0·35

Zeugopterus unimaculatus Bnp.

Fourteen specimens of post-larvæ one-spotted topknots were taken in 1914. The only previous records are those of Clark, who found three specimens in June and July, 1913. The 1914 records are of specimens taken in May and the early part of June. The species is easily distinguished from the other topknots.

TABLE XXIX.

RECORD OF ZEUGOPTERUS UNIMACULATUS Gthr.

No. of haul.	Date.	Depth.	No.	Size in mm.
XI.	19.v.14	S.	1	8
XIII.	19.v.14	M.	1	5·5
XIV.	25.v.14	M.	1	6·5
XV.	25.v.14	S.	1	8·7
XVI.	25.v.14	S.	1	8
XVII.	3.vi.14	B.	3	6–6·5
XVIII.	3.vi.14	B.	2	6–6·2
XXI.	11.vi.14	M.	1	8·6
XXII.	11.vi.14	M.	1	9·3
XXIII.	11.vi.14	B.	2	8–9·4

Zeugopterus punctatus Blainv.

In 1914 the post-larvæ were much more frequent in May than in June, indeed they practically disappeared after the beginning of the latter month. The maximum frequency for the whole period 1906–14 occurred in April, though the figure is based on too few hauls to be very reliable. It is clear, however, that the species must have its maximum spawning period in the early months of the year.

TABLE XXX.

RECORD OF ZEUGOPTERUS PUNCTATUS Bl.

No. of haul.	Date.	Depth.	No.	Size in mm.
IX.(5)	15.v.14	B.	1	7
X.	19.v.14	M.	7	5–8
XI.	19.v.14	S.	1	6·5
XII.	19.v.14	S.	2	8·5, 8.5
XIII.	19.v.14	M.	4	6.5–8.5
XIII.a	22.v.14	—	10	5·5–7
XIV.	25.v.14	M.	1	7·5
XV.	25.v.14	S.	1	8
XVI.	25.v.14	S.	7	8·5–10·2
XVII.	3.vi.14	B.	2	6·5–6·7
XVIII.	3.vi.14	B.	1	7·3
XIX.	3.vi.14	M.	1	6
XXII.	11.vi.14	M.	1	7·6

TABLE XXXI.

ZEUGOPTERUS PUNCTATUS.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
April . . .	7	3	16	3–6	2·3
May	30	13	44	5–10·2	1·5
June	106	14	27	5·5–11·69	0·25

Sub-fam. SOLEINÆ.

Solea vulgaris Quens.

The majority of the specimens of post-larvæ of the common sole were taken in May. The number captured was, however, not large and was below that of the thickback sole (*S. variegata*).

Solea variegata Don.

These were taken in considerable numbers during May and a few were also present in June. The maximum number taken in one haul was 48, in marked contrast to *S. vulgaris*, of which only one specimen occurred in a haul, except in two cases where there were 2 and 4 specimens.

Solea lascaris Risso.

Only two specimens were found in the 1914 material, taken on the 22nd July. Previous records made by Clark in 1913 are in July, August, and September.

Solea lutea Risso.

Not a single specimen of *S. lutea* was recognised in the 1914 material, although in 1913 Clark found a fair number in June, a month which is well represented in the 1914 hauls.

TABLE XXXII.

Record of Solea.

			S. vulgaris.		S. variegata.		S. lascaris.	
No. of haul.	Date.	Depth.	No.	Size in mm.	No.	Size in mm.	No.	Size in mm.
V.	29.iv.14	B.	1	5·7	—	—	—	—
VI.	,,	M.	1	7·5	—	—	—	—
IX.(5)	15.v.14	B.	1	7	—	—	—	—
X.	19.v.14	M.	1	6·9	33	4–8·2	—	—
XI.	,,	S.	—	—	41	4–9·5	—	—
XII.	,,	S.	—	—	21	5·5–9·2	—	—
XIII.	,,	M.	—	—	48	4·5–10·2	—	—
XIII.(a)	22.v.14	—	1	6·4	11	4·5–8·5	—	—
XIV.	25.v.14	M.	1	6·6	43	4·2–12·3	—	—
XV.	,,	S.	2	6·6, 7·7	3	9·2–9·8	—	—
XVI.	,,	S.	4	6·2–8·7	9	5–9·8	—	—
XVII.	3.vi.14	B.	—	—	5	5·3–7·5	—	—
XVIII.	,,	B.	1	5	—	—	—	—
XXII.	11.vi.14	M.	—	—	2	6·4–7	—	—
XXIII.	,,	B.	—	—	6	6·5–8·5	—	—
XXXVII.	24.vi.14	B.	—	—	2	3·6–5·6	—	—
LXIV.	22.vii.14	B.	—	—	—	—	1	10·3
LXV.	,,	B.	—	—	—	—	1	9·6

TABLE XXXIII.

Solea vulgaris.

Month.	Total number of hauls 1906–1914.	Number of hauls in which the species occurs.	Number of specimens.	Size in mm.	Average number per haul.
April	7	2	2	5·7–7·5	0·3
May	30	11	19	4–10·5	0·63
June	106	5	5	5–8·7	0·05

TABLE XXXIV.

Solea variegata.

Month.	Total number of hauls 1906–1914.	Number of hauls in which it occurs.	Number of specimens.	Size in mm.	Average number per haul.
May	30	11	288	4–12·3	9·6
June	106	26	170	3–11	1·6
July	94	3	4	4·5–10	0·04
August . . .	75	4	7	4–8·5	0·09

GOBIIDÆ.

Gobius sp. *Crystallogobius nilssoni* Düb. and Kör.
Aphya pellucida Nardo.

Table XXXV. gives the record of all the gobies which have not been specifically determined, and the list probably includes many young stages of both *Crystallogobius nilssoni* and *Aphya pellucida*. The larger specimens, probably chiefly belong to *Gobius minutus* Pall., though other species may be included.

Tables XXXVI. and XXXVII. give the records of those specimens, chiefly the larger ones, of Crystallogobius and Aphya which could be determined with some certainty. The separation of the different species has been too incomplete to make it advisable to draw conclusions as to seasonal distribution.

TABLE XXXV.

RECORD OF GOBIUS SP.

No. of haul.	Date.	Depth.	No.	Size in mm.
XI.	19.v.14	S.	1	13
XII.	,,	S.	2	9·5–12·5
XIII.	,,	M.	5	10–12·5
XIII. a	22.v.14	—	63	8–14, 24
XIV.	25.v.14	M.	13	9·6–13·3
XV.	,,	S.	3	7–11·5
XVI.	,,	S.	18	6·5–15
XX.	10.vi.14	S.–M.	1	14·5
XXII.	11.vi.14	M.–B.	6	12·6–14
XXIII.	,,	B.	5	12·5–15
XXV.	16.vi.14	B.	1	7
XXVIII.	,,	B.	1	7
XLIV.	29.vi.14	M.	3	10–14
XLVI.	2.vii.14	S.	73	7–22·6
XLVII.	,,	S.	87	6–19·5
XLVIII.	,,	M.	59	7–18
XLIX.	,,	M.–B.	17	10–16
LI.	6.vii.14	B.	3	6–7·5
LIII.	6.vii.14	B.	1	10·2
LIV.	9.vii.14	S.	3	5–7
LV.	,,	M.	1	5
LVI.	,,	B.	1	5

TABLE XXXV. (*continued.*).

No. of haul.	Date.	Depth.	No.	Size in mm.
LVII.	9.vii.14	B.	5	4·5–11
LIX.	15.vii.14	M.	83	6–19
LX.	,,	M.	52	7–19
LXI.	16.vii.14	B.	82	6·7–18·6
LXII.	,,	B.	11	5·7–27
LXV.	22.vii.14	B.	3	10–11·5
LXVII.	,,	M.	1	6·6
LXVIII.	,,	B.	7	3·2–8·5
LXXI.	,,	B.	6	7·5–12
LXXIII.	29.vii.14	M.	1	10
LXXVII.	,,	B.	6	7–10
LXXVIII.	,,	M.	1	6
LXXXI.	,,	M.	3	10–11·6
LXXXIII.	,,	B.	1	12
LXXXVII.	4.ix.14	M.	1	14

TABLE XXXVI.

RECORD OF CRYSTALLOGOBIUS NILSSONI.

No. of haul.	Date.	Depth.	No.	Size in mm.
IX.(5)	15.v.14	B.	2	9–11·5
XII.	19.v.14	S.	6	24–27
XIII.	,,	M.	150	17–36
XIV.	25.v.14	M.	40	18–31 ca.
XV.	,,	S.	11	10–27
XVI.	,,	S.	3	11·5–28
XXII.	11.vi.14	M.–B.	4	26·5–37
XXXII.	17.vi.14	S.	1	Fragment of large one.
XLIII.	29.vi.14	B.	3	25 ca.–30
LVI.	9.vii.14	B.	1	27
LVII.	,,	B.	2	22–28
LIX.	15.vii.14	M.	12	27–37·5
LX.	15.vii.14	M.	20	8–29·5
LXI.	16.vii.14	B.	18	26–29
LXXI.	22.vii.14	B.	8	22–38
LXXIII.	29.vii.14	M.	1	12

TABLE XXXVII.

RECORD OF APHYA PELLUCIDA.

No. of haul.	Date.	Depth.	No.	Size in mm.
XIV.	25.v.14	M.	2	8, 13
XV.	,,	S.	3	6·6–13
XVI.	,,	S.	1	11·5
XVIII.	3.vi.14	B.	2	6–6·2
XX.	10.vi.14	S.–M.	3	13·5–15
XXI.	11.vi.14	M.	3	11·5–16·5
XXII.	11.vi.14	M.–B.	3	13·2–15·3
XXIII.	11.vi.14	B.	4	7·6–16
XXXVII.	24.vi.14	B.	3	6·5–8·5
XLIII.	29.vi.14	B.	2	10 ca.–12
LXIII.	22.vii.14	B.	50	7·5–11
LXIV.	22.vii.14	B.	1	10
LXV.	,,	B.	6	10·5–12·5
LXVI.	,,	M.	1	10
LXXV.	29.vii.14	B.	1	11
LXXXII.	,,	M.	1	11 ca.
LXXXVI.	12.viii.14	B.–M.	1	11

CYCLOPTERIDÆ.

Cyclopterus lumpus L.

One specimen of the lump sucker was obtained in the young-fish trawl in 1914. It was found in Haul XLI., 3½ miles S.W. by W. of the Eddystone, a bottom haul made on June 26th, 1914. The length of the specimen was 16·5 mm. Clark records one specimen 18 mm. long in 1913.

TRIGLIDÆ.

Trigla gurnardus L. *T. hirundo* Bl.

The characters by means of which post-larval stages of *T. gurnardus* and *T. hirundo* may be distinguished have been pointed out by Clark (**1914**) in his report on the post-larval teleosteans of Plymouth. The specimens which were most numerous in the 1914 material belong to the *T. gurnardus* type, with long pectoral fins which are pigmented chiefly on the posterior half of the fin. From specimens of this type young *T. hirundo* with short, broad pectorals pigmented over the whole surface, are easily and definitely distinguishable.

Clark refers to specimens appearing in August and September which he thinks are quite distinct from *T. gurnardus* and *T. hirundo*, and have very little pigment. These he regards as probably belonging to the species *T. lineata*. A few specimens amongst the 1914 material, which I have included under the *gurnardus* type, very closely approach the forms which Clark thus regards as *T. lineata*, the amount of pigment on the pectoral fins being small, although the fins are long. The variation in the amount of pigment seen in preserved material, especially when the preservation is not very good, is considerable, and seems to me to make it impossible to assign every specimen to a particular species with any degree of certainty until some more definite character can be used for purposes of investigation.

It must be borne in mind too that the species which as an adult is perhaps the most numerous on the grounds in the neighbourhood where most of the hauls have been made is *T. cuculus*, and so far as I am aware the young stages of that form have never been recognised. It is possible, therefore, that this species may be included amongst the forms with long pectorals pigmented on the posterior half, which are here included under *Trigla sp.*, and amongst those which Clark recorded as *T. gurnardus*. A fourth species, *T. lyra*, is occasionally found in the western part of the English Channel, concerning the young stages of which nothing is known.

Unfortunately the numerical characters, such as number of fin rays and vertebræ, of these gurnards are all so similar that they cannot be used for discriminating the species in these young stages.

TABLE XXXVIII.

Record of Trigla sp.

			Trigla sp.		T. hirundo.	
No. of haul.	Date.	Depth.	No.	Size in mm.	No.	Size in mm.
IX.(5)	15.v.14	B.	3	7·5–9·5	—	—
X.	19.v.14	M.	53	4·5–11·7	—	—
XI.	,,	S.	39	6–9·5	—	—
XII.	,,	S.	8	5·1–10	—	—
XIII.	,,	M.	13	6–8·2	—	—
XIII. a	22.v.14	—	9	7·5–10	—	—
XIV.	25.v.14	M.	45	5·5–13	—	—
XV.	25.v.14	S.	33	7·2–12·5	—	—
XVI.	,,	S.	41	5·5–12·7	—	—
XVII.	3.vi.14	B.	77	5–11·5	—	—
XVIII.	,,	B.	63	5·5–18	1	18
XIX.	,,	M.	15	6–11·5	—	—

TABLE XXXVIII. (*continued.*).

No. of haul.	Date.	Depth.	Trigla sp. No.	Size in mm.	T. hirundo. No.	Size in mm.
XX.	10.vi.14	S.–M.	4	9–10·8		—
XXI.	11.vi.14	M.	9	8·7–10·5	—	—
XXII.	,,	M.–B.	12	8·2–15		
XXIII.	,,	B.	21	7–11·5	—	—
XXIV.	16.vi.14	B.	2	8, 8·5		—
XXV.	,,	B.	1	10 ca.	—	—
XXVI.	,,	B.	19	5·6–16·5	—	—
XXVII.	,,	M.	5	7–9		—
XXX.	17.vi.14	M.	2	7·7–8·5	—	
XXXI.	,,	M.	2	7·5–8·4	—	—
XXXV.	19.vi.14	M.	2	12–13		—
XXXVI.	24.vi.14	B.	1	7·7	1	10·5
XXXVII.	,,	B.	3	6·8–7·7		—
XXXVIII.	,,	M.	1	11	1	7
XLII.	29.vi.14	B.	1	10·5	—	—
XLIII.	,,	B.	7	6·5–12		
XLIV.	,,	M.	2	9–13·5		—
XLV.	,,	—	—	—	1	12 ca.
XLVI.	2.vii.14	S.	5	9·5–10·5	—	—
XLVII.	2.vii.14	S.	1	10·8	—	—
LVIII.	9.vii.14	M.	2	13–16	—	—
LX.	15.vii.14	M.	1	12	—	—
LXVIII.	22.vii.14	B.	—	—	2	8–10
LXIX.	,,	S.	—	—	1	9·5
LXXIII.	29.vii.14	M.	1	11	—	—
LXXIV.	,,	M.	—	—	1	11 ca
LXXV.	,,	B.	1	10	—	—
LXXVI.	,,	M.	1	11·7	—	—
LXXVIII.	,,	M.	2	9–19	—	—
LXXXV.	12.viii.14	M.	5	13·5–19	—	—

TRACHINIDÆ.

Trachinus vipera Cuv.

The 1914 records are given in Table XXXIX. and monthly summaries for the period 1906–14 in Table XL. In 1914 no specimens were observed during May and the first half of June, the first record being on June 16th. Over the whole period the average number per haul is highest in July and August, being slightly though perhaps not significantly higher in August than in July. In September there is a rapid disappearance of specimens in the hauls.

No specimens of *Trachinus draco* were recognised in the 1914 material. Clark obtained four specimens of this species in August and September, 1913.

TABLE XXXIX.

Record of Trachinus vipera.

No. of haul.	Date.	Depth.	No.	Size in mm.
XXV.	16.vi.14	B.	3	5·2–7
XXVI.	,,	B.	2	5·6–8·2
XXXIV.	19.vi.14	M.	3	6·6–8·5
XXXV.	,,	M.	3	6·5–7·5
XXXVI.	24.vi.14	B.	1	7
XXXVII.	,,	B.	1	7·5
XXXVIII.	,,	M.	2	5·6–6·5
XXXIX.	,,	S.	1	9
L.	6.vii.14	B.	4	all 5 mm.
LI.	,,	B.	9	4·5–7·5
LII.	,,	M.	7	5–6
LV.	9.vii.14	M.	2	6–7
LIX.	15.vii.14	M.	8	5·5–7·8
LXI.	16.vii.14	B.	1	5·5
LXII.	,,	B.	2	5–7
LXVII.	22.vii.14	M.	5	6·5–8
LXVIII.	,,	B.	6	5·2–9·3
LXIX.	,,	S.	7	4·3–8·3
LXX.	,,	M.	1	5·5
LXXIII.	29.vii.14	M.	1	11·6
LXXIV.	,,	M.	3	6·5–7·5
LXXV.	,,	B.	1	8·5
LXXVI.	,,	M.	1	11·5
LXXVIII.	,,	M.	4	6·2–10·7
LXXXIII.	,,	B.	2	5·5–8·7
LXXXVI.	12.viii.14	B.–M.	1	7

TABLE XL.

Trachinus vipera.

Month.	Total number of hauls 1906–1914.	Number of hauls in which it occurs.	Number of specimens.	Size in mm.	Average number per haul.
April	7	1	1	3·5	0·1
May	30	1	1	3·5	0·03
June	106	22	80	2·5–9	0·75
July	94	45	335	3–11·6	3·6
August . . .	75	52	292	2·7–18	3·9
September . . .	85	26	42	3·5–18	0·5

CALLIONYMIDÆ.

Callionymus lyra L.

Post-larval dragonets are more constantly met with in the hauls and occur in greater numbers than any other species of teleostean, being specially abundant in May and June. The 1914 records are given in Table XLI., and the monthly summaries in Table XLII.

TABLE XLI.

Record of Callionymus lyra.

No. of haul.	Date.	Depth.	No.	Size in mm.
V.	29.iv.14	B.	5	4–7
VI.	,,	M.	4	5–7
VII.	,,	S.	5	3–6
VIII. (1)	8.v.14	M.	1	6·3
IX. (1)	15.v.14	M.	67	5–7·5
IX. (5)	,,	B.	108	4–7
XII.	19.v.14	S.	5	5–10·5
XIII.	,,	M.	20	4·5–11
XIII.a	22.v.14	—	34	5–9
XIV.	25.v.14	M.	4	5·5–7
XV.	,,	S.	4	8–10·5
XVI.	,,	S.	3	5·5–6
XVII.	3.vi.14	B.	105	4–7
XVIII.	,,	B.	59	3·5–7
XIX.	,,	M.	15	4·5–8
XX.	10.vi.14	S.–M.	2	5·5–6·3
XXI.	11.vi.14	M.	9	5·2–11
XXII.	,,	M.–B.	16	6–12

TABLE XLI. (*continued*).

No. of haul.	Date.	Depth.	No.	Size in mm.
XXIII.	11.vi.14	B.	41	5–13·5
XXIV.	16.vi.14	B.	2	6·7–10·2
XXV.	,,	B.	27	3·8–8
XXVII.	,,	M.	1	7
XXIX.	17.vi.14	B.	1	7·3
XXX.	,,	M.	14	3·7–8·3
XXXI.	,,	M.	30	3–9
XXXII.	,,	S.	17	4–6
XXXIII.	19.vi.14	M.	1	7·7
XXXIV.	,,	M.	1	7
XXXV.	,,	M.	10	5·5–8·7
XXXVI.	24.vi.14	B.	2	3·2–6·6
XXXVII.	,,	B.	54	4·5–8
XLII.	29.vi.14	B.	11	7–8·5
XLIII.	,,	B.	37	5·5–8·7
XLIV.	,,	M.	13	5·5–8
XLV.	,,	S.	1	6
XLVI.	2.vii.14	S.	165	6–12
XLVII.	,,	S.	98	5·5–12·2
XLVIII.	,,	M.	94	4–12·2
XLIX.	,,	M.–B.	47	5·5–11·5
L.	6.vii.14	B.	2	10–13·5
LI.	,,	B.	2	7·5–9
LIV.	9.vii.14	S.	2	6–6·5
LV.	,,	M.	1	5·3
LVI.	,,	B.	1	6
LVII.	,,	B.	3	6·7–7·1
LIX.	15.vii.14	M.	6	6·5–8·5
LXI.	16.vii.14	B.	4	7·5–11
LXII.	,,	B.	2	5–6
LXVII.	22.vii.14	M.	1	6·5
LXVIII.	,,	B.	10	4·5–7·3
LXIX.	,,	S.	1	6·5
LXX.	,,	M.	1	6
LXXIII.	29.vii.14	M.	8	6·5–8
LXXIV.	,,	M.	3	6·5–7·5
LXXVI.	,,	M.	2	9·2
LXXVII.	,,	B.	4	6·5–8·5
LXXXIV.	,,	B.	1	8

TABLE XLII.

CALLIONYMUS LYRA.

Month.	Total number of hauls 1906–1914.	Number of hauls in which it occurs.	Number of specimens.	Size in mm.	Average number per haul.
March . . .	2	2	36	2·5–6	18
April . . .	7	6	46	2·5–12	6·6
May	30	21	654*	2·5–11	21·8
June	106	77	1890*	2–14	17·8
July	94	57	933	2·5–13·5	10
August . . .	75	43	279	2·75–13	3·7
September . . .	85	20	56	4–10	0·7
October . . .	14	1	1	5	0·07

GOBIESOCIDÆ.

Lepadogaster.

Eighteen post-larval specimens were obtained in 1914, thirteen of which occurred in July. According to Clark's records (**1914**) specimens may occur from June to September.

TABLE XLIII.

RECORD OF LEPADOGASTER SP.

No. of haul.	Date.	Depth.	No.	Size in mm.
XXIII.	11.vi.14	B.	1	10·5
XLVI.	2.vii.14	S.	5	10–12
XLVII.	,,	S.	1	11·2
XLVIII.	,,	M.	3	8·6–11·7
LV.	9.vii.14	M.	1	6·5
LVII.	,,	B.	2	7·5
LIX.	15.vii.14	M.	1	10
LXXXVI.	12.viii.14	B.–M.	4	10–11·2

BLENNIIDÆ.

Probably two species at least are represented in the material, *Blennius pholis* L. and *Blennius ocellaris* L., but I have not succeeded in separating them with certainty. The records are shown in Table XLIV.

---

* m. (=many) has been counted as 50, and v.m. (=very many) as 100. The figures for May and June are therefore approximations only

TABLE XLIV.

Record of Blennius sp.

No. of haul.	Date.	Depth.	No.	Size in mm.
XXV.	16.vi.14	B.	1	6·5
XXVII.	,,	M.	1	7
XXXVII.	24.vi.14	B.	1	5·5
XXXIX.	,,	S.	1	9
XLVI.	2.vii.14	S.	2	8–9
XLVII.	,,	S.	2	8·5–9·5
XLVIII.	,,	M.	1	12·5
L.	6.vii.14	B.	1	6·4
LI.	,,	B.	1	7·5
LIV.	9.vii.14	S.	1	17
,,	,,	,,	6	6–8·5
LV.	,,	M.	1	6
LVIII.	,,	M.	2	12–13·5
LXIV.	22.vii.14	B.	2	17·5
LXV.	,,	B.	1	17
LXVIII.	,,	B.	3	7–9·8
LXXIII.	29.vii.14	M.	1	12
LXXV.	,,	B.	1	7
LXXV.	,,	B.	1	8·5
LXXXIII.	,,	B.	1	8
LXXXVII.	4.ix.14	M.	4	8·3–11·5

Fig. 8.—*Lophius piscatorius* L. Length 6·2 mm. July 16th, 1914.

PEDICULATI.

Lophius piscatorius L.

One specimen of an early stage, 6·2 mm. long was found in Haul LXII., taken near the bottom 7 miles west of Rame Head on July 16th, 1914. A figure of this specimen drawn by Mrs. Sexton is reproduced as Fig. 8. The great resemblance of this figure with Emery's figure, which is reproduced by Ehrenbaum in *Nordisches Plankton*, p. 303, Fig. 108, b, and ascribed by both authors to *Macrurus*, may be pointed out. It seems to me very probable that that figure should really be assigned to *Lophius*.

The larva of *Lophius piscatorius* is figured by Danois (**1913**, p. 164, Fig. 319). Ehrenbaum (**1905–9**) reproduces Agassiz and Whitman's figures of American specimens.

SUMMARY.

Table XLV. is perhaps of interest, as showing the composition of the catch obtained with the young-fish trawl at different times of the year. It has been obtained by combining certain groups of hauls made in 1914 in the offshore waters outside Plymouth, all of them being beyond the 20-fathom line. As far as the conditions are concerned therefore the different groups are fairly comparable. The figure given for each species is the average number of specimens per haul for the group. It will be seen that after June the number of species present as well as the average number per haul are both very much reduced.

TABLE XLV.

Averages per Haul in Different Groups of Hauls.

	X.–XIII. S. of Eddystone May 19,'14. 27–39 fms.	XIV.–XVI. S. of Eddystone May 25,'14. 35–37 fms.	XVII.–XXIII. W. of Rame June 3-11, 1914. 26–27 fms.	XXXV. to XLI. Eddystone June 19–26, 1914. 23–39 fms.	LXVII. to LXX. Eddystone July 22,'14 32–38 fms.	LXXIII. to LXXVIII. Eddystone July 29,'14. 20–35 fms.	LXXXV. and LXXXVI. W. of Rame Aug. 12,'14 26–27 fms.
Clupea . . .	217	v.m.	v.m.	11	11	2	—
Ammodytes . .	0·7	1	4	3	7	3	—
Gadus pollachius . .	2	—	—	—	0·2	—	—
,, merlangus . .	6	13	9	0·5	—	—	—
,, minutus . .	44	47	2	4	0·2	0·2	—
,, luscus . .	3	6	0·4	0·3	—	—	—
Molva molva . .	0·2	0·7	0·4	0·2	—	—	—
Raniceps raninus . .		—	—	—	—	0·2	—
Onos mustelus . .	3	9	0·7	0·7	—	0·2	—
Labrus bergylta . .	0·5	2	3	—	—	0·2	2
Labrus mixtus . .	0·2	1	0·7	0·2	0·5	—	—

v.m.=very many.

TABLE XLV. (*continued*).

	X.-XIII. S. of Eddystone May 19, '14. 27-39 fms.	XIV.-XVI. S. of Eddystone May 25, '14. 35-37 fms.	XVII.-XXIII. W. of Rame June 3-11, 1914. 26-27 fms.	XXXV. to XLI. Eddystone June 19-26, 1914. 23-39 fms.	LXVII. to LXX. Eddystone July 22, '14. 32-38 fms.	LXXIII. to LXXVIII. Eddystone July 29, '14. 20-35 fms.	LXXXV. and LXXXVI. W. of Rame Aug. 12, '14 26-27 fms.
Ctenolabrus rupestris .	—	—	—	0·5	0·2	0·5	0·5
Scomber scomber . .	—	28	7	2	0·5	—	—
Pleuronectes limanda .	29	358	22	0·2	—	—	—
,, microcephalus	34	15	8	0·5	0·2	0·2	—
Arnoglossus laterna .	0·5	8	21	3	3	6	1
Rhombus maximus .	—	—	—	—	—	0·3	—
,, laevis .	—	1	0·3	—	0·2	0·2	0·5
Scophthalmus norvegicus	66	4	19	—	0·2	—	—
Zeugopterus punctatus .	4	3	0·7	—	—	—	—
,, unimaculatus	0·5	1	1	—	—	—	—
Solea vulgaris . .	0·2	2	0·1	—	—	—	—
,, variegata . .	36	18	2	0·3	—	—	—
Gobius sp. . . .	2	11	2	—	2	1	—
Crystallogobius nilssoni	39	18	0·6	—	—	0·2	—
Aphya pellucida . .	—	2	2	0·5	—	0·2	0·5
Cyclopterus lumpus .	—	—	—	0·2	—	—	—
Trigla gurnardus . .	28	40	29	1	—	1	2
,, hirundo . .	—	—	0·1	0·3	1	0·2	—
Trachinus vipera . .	—	—	—	1	5	2	0·5
Callionymus lyra . .	6	4	35	11	3	3	—
Lepadogaster . .	—	—	0·1	—	—	—	2
Blennius . . .	—	—	—	0·3	1	0·5	—

LITERATURE.

1887. Matthews, J. Duncan.—Note on the Ova, Fry and Nest of the Ballan Wrasse. 5th Ann. Rep. Fish. Bd. Scotland.

1888. Raffaele, F.—Mitteil. Zool. Sta. Neapel. VIII.

1899. Holt, E. W. L.—Recherches sur la reproduction des poissons osseux. Ann. Mus. d'Hist. Nat. Marseille. Zoologie. T. V.

1905–9. Ehrenbaum, E.—Eier und Larven von Fischen. *Nordisches Plankton.* IV. and X.

1910. Hefford, A. E.—Notes on Teleostean Ova and Larvæ observed at Plymouth in Spring and Summer, 1909. Journ. Mar. Biol. Assoc. IX. p. 1.

1913. Danois, E.—Contribution à l'étude systématique et biologique des poissons de la manche occidentale. Paris. Masson et Cie.

1914. Clark, R. S.—General Report on the Larval and Post-Larval Teleosteans in Plymouth Waters. Journ. Mar. Biol. Assoc. X. p. 327.

On the Amount of Phosphoric Acid in the Sea-Water off Plymouth Sound. II.

By

Donald J. Matthews.

With one Figure in the Text.

In a previous paper* the writer gave the results of the determination of the phosphates in sea-water, by means of Pouget and Chouchak's reagent, on a number of samples collected between September 13, 1915, and February 5, 1916, at the Knap Buoy, half a mile outside the breakwater at Plymouth.

The analyses have been continued so as to cover a period of sixteen months and show a large seasonal variation.

The method is described in detail in the previous paper, and consists in throwing down the phosphoric acid with iron and an alkali, treating with nitric acid, and determining the amount colorimetrically in the Dubosq apparatus after adding nitromolybdate of strychnine. A few modifications have been made and are described below.

In the first place, as the pressure of other work made it impossible to examine all samples immediately after collection, they were sterilised as soon as taken with toluol or chloroform. Toluol was perfectly satisfactory, but the chloroform in some cases threw down a precipitate on standing, and the absence of figures for July, August, November and December, 1916, is due to the loss of samples from this cause. If the sample is allowed to stand without previous sterilisation the phosphates decrease and may be entirely removed in a few weeks.

The standard phosphate solution contained 0·003 mg. of P_2O_5 in one cubic centimetre, and was made up in approximately decinormal nitric acid to prevent the growth of moulds.

For the precipitation of the iron, sodium carbonate was used instead of ammonia and ammonium chloride ; 1 ccm. of 2 N solution for 1 ccm. of iron solution was sufficient to more than neutralise the excess acid of the latter.

In some instances the iron precipitate was greasy and was difficult to dissolve off the paper completely, so the following method was adopted. Five cubic centimetres of strong hydrochloric acid were poured into the beaker in which precipitation had taken place and distributed over the walls to dissolve any iron; then 10 ccm. of water were added, the beaker was warmed for a few minutes, and the hot dilute acid was allowed to drop on to the filter paper by means of a small pipette provided with a rubber-teat head. The beaker and paper were well washed and the latter incinerated in a platinum crucible; the ash was dissolved in a little strong hydrochloric acid and added to the rest of the solution, which was then evaporated to dryness on the water-bath; the chlorides were converted to nitrates by evaporation to dryness with 10 ccm. of the dilute nitric acid, taken up in more nitric acid, using 7 ccm. of 25% by volume if the final bulk was to be 50 ccm. The analysis was then carried out as described in the previous paper. In an extreme case the dirty residue on the paper was found to contain 0·0024 mg. of P_2O_5. The origin of the greasy matter is unknown; it may be due to the drainage from the port, or, on the other hand, it may be the volatile oily substance which so often renders the distillate turbid when sea-water is boiled with an alkali for the determination of ammonia.

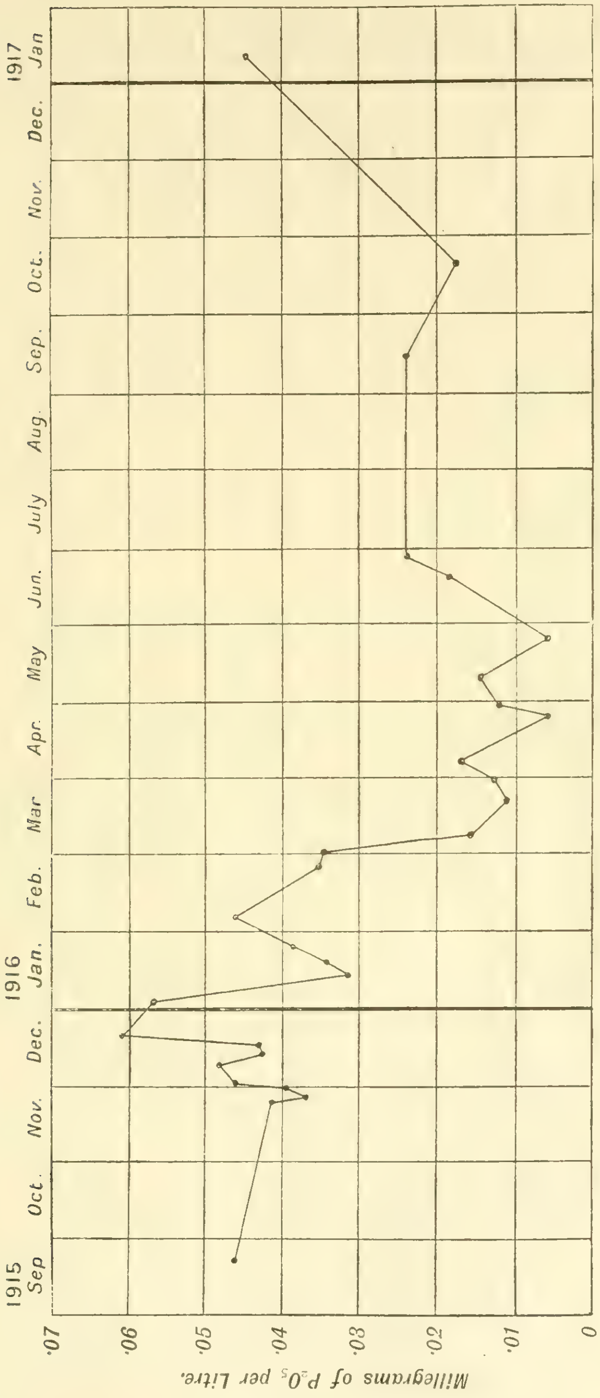
---

* Matthews, D. J., "On the Amount of Phosphoric Acid in the Sea-Water off Plymouth Sound." This Journal, xi., No. 1, p. 122, March, 1916.

It was mentioned in the earlier paper that the amount of phosphates found was increased if the water was previously oxidised with a permanganate. Attempts to find a suitable method for determining this excess phosphorus have been only partly successful. It is necessary to use strong oxidising substances which do not interfere with subsequent operations and are easily purified. In the end the following process was adopted. From 200 ccm. to 400 ccm. of the water were evaporated in a porcelain basin holding nearly 200 ccm. until the bulk of the salts had separated; then 10 ccm. or 20 ccm. of strong nitric acid were added, according to the amount of sample taken, the dish was covered, and heating continued until the evolution of brown fumes had ceased. The cover was removed and the evaporation was continued to dryness; the dish was then heated over an argand burner until the salts were in gentle fusion and the nitrates of the earths were decomposed with evolution of brown fumes.

The dish was allowed to cool and the salts were dissolved by warming for an hour with 150 ccm. of water and 1 ccm. of strong hydrochloric acid. Iron was added and 5 ccm. of 2 N sodium carbonate solution and the analysis completed as before. There is danger of the porcelain being attacked unless it is very carefully heated, and unless it is certain that it gives up no phosphates under this treatment it would probably be better to use fused silica basins.

The blank on the reagents used in the analyses reported in the previous



Phosphates In Water at Knap Buoy, Plymouth Sound.

paper was 0·0036 mg. of P_2O_5. A repurification of the iron, acids, alkali and water reduced it to 0·0026 mg., and a second purification to 0·0021 mg. The blank on the amounts required for the estimation of total phosphorus was at first 0·0066 mg. and afterwards 0·0061 mg. The blanks were determined both by carrying out analyses on distilled water, to which 0·0300 mg. of P_2O_5 had been added, and also with small amounts of water, the final solution being made up to 10 ccm. and compared in a special small colorimeter tube holding only 10 ccm. The results agreed excellently.

The determination of the small amounts of phosphoric acid found during the summer presented considerable difficulty. Making the final volume 10 ccm. gave rather discordant results, and it was subsequently found that the closest agreement was obtained between duplicates if enough of the standard solution was added to the sample to bring the content up to about 0·035 mg. of P_2O_5 per litre, the final volume being 50 ccm. This gives a strong colour in a depth of 40 mm. and at the same time avoids the errors which arise when very small volumes of liquid are to be manipulated.

The whole of the results obtained by the colorimetric method are given in the following table, and those for phosphoric acid are plotted in the curve; the figures for February 17th, 1915, have not been used in this case as the sample was by an oversight allowed to stand unsterilised for six days.

SURFACE SAMPLES TAKEN AT THE KNAP BUOY.

Date.	G.M.T.	S.‰.	Phosphates. P_2O_5 mg. per litre. Found in duplicates.	Mean.	Total P calculated to P_2O_5 mg. per litre.
1915					
Sept. 21	10.30 a.m.	34·96	—	0·046	—
Nov. 24	11.35 a.m.	34·78	0·042, 0·041	0·0415	—
,, 26	11.45 a.m.	34·43	0·040, 0·034	0·037	—
,, 29	11.10 a.m.	34·14	0·040, 0·037	0·0385	—
Dec. 2	12.20 p.m.	—	0·0484, 0·0435	0·0460	—
,, 9	10.30 a.m.	31·46	0·049, 0·047	0·048	—
,, 13	11.30 a.m.	—	0·044, 0·041	0·0425	—
,, 16	12.10 p.m.	26·20	—	0·043	—
,, 20	11.25 a.m.	29·69	0·058, 0·064	0·061	—
1916					
Jan. 3	11.35 a.m.	25·66	0·057, 0·057	0·057	—
,, 14	1.55 p.m.	33·87	0·0318, 0·0316	0·0317	—
,, 18	2.30 p.m.	33·93	0·0336, 0·0348	0·0342	—

			Phosphates. P_2O_5 mg. per litre.		Total P calculated to P_2O_5 mg. per litre.
Date.	G.M.T.	S.‰.	Found in duplicates.	Mean.	
Jan. 24	11.20 a.m.	33·42	0·0378, 0·0391	0·0384	—
Feb. 5	12.30 p.m.	31·58	0·0507, 0·0414	0·0460	—
,, 17	10.45 a.m.	—	0·0190, 0·0190	(0·0190)	0·0323
,, 25	11.0 a.m.	33·30	0·0371, 0·0343	0·0357	—
Mar. 1	11.40 a.m.	33·82	—	0·0350	0·039
,, 8	11.15 a.m.	34·54	0·0201, 0·0115	0·0158	—
,, 21	11.50 a.m.	34·54	0·0101, 0·0122	0·0111	0·050
,, 29	11.45 a.m.	32·18	0·0104, 0·0148	0·0126	0·045
April 6	11.55 a.m.	34·40	0·0160, 0·0180	0·0170	0·016
,, 24	11.10 a.m.	34·40	—	0·0056	—
,, 28	—	34·40	0·0117, 0·0124	0·0120	0·035
May 9	10·50 a.m.	34·16	0·0158, 0·0130	0·0144	0·046
,, 24	11.45 a.m.	34·60	0·0053, 0·0064	0·0058	—
June 19	10.45 a.m.	34·90	0·0185, 0·0184	0·0184	0·036
,, 27	11.45 a.m.	—	0·0230, 0·0248	0·0239	0·038
Sept. 13	noon	—	0·0277, 0·0198	0·0238	0·024
Oct. 19	10.45 a.m.	33·93	0·0194, 0·0155	0·0174	0·029
1917					
Jan. 10	12.30 p.m.	33·62	0·0435, 0·0448	0·0442	0·049

In the first place it is clear that the results given in the previous paper which were obtained by precipitating the phosphorus with iron and then weighing as phosphomolybdic anhydride are seriously in error, and it was found that molybdic acid was thrown down at the same time.

The data of the present table show that there is a large seasonal variation, the maximum being more than ten times as large as the minimum. At first it was expected that the curve would agree with that for the phytoplankton inverted, but this is not the case. Miss Lebour* has made counts of the diatoms at the surface, 5 fthms. and 7 fthms. on 330 samples taken on 110 days at the Knap Buoy from September 21, 1915, to September 18, 1916. The average number in 1 ccm. for October, 1915, was 17, and in November 9, while in December and in January, February and March, 1916, there were only one or two. The maximum number for the year, 38, occurred in April, 1916, the high value being due to the last week of the month, 45 being counted on the 25th and 137 on the 27th. Then a decline set in, with 30 per cubic centimetre in May and only 9 in June. In July there was a rise to 21 and a secondary maximum of 31 in August, followed by a fall to 17 in September. The curve shows that the maximum value for phosphates, 0·061 mg. of P_2O_5 per litre, coincided with the smallest number of diatoms, and also with the shortest days of the year. The phosphates then commenced to fall at once, irregularly at first it is true, to a minimum, of less than one-tenth of the maximum, at the end of April, which coincides with the diatom maximum for the year. The number of diatoms fell off at the beginning of May, while the phosphate minimum continued to the last week of the month. At this period, however, the alga *Phæocystis* appeared in enormous quantities. It was first abundant on April 25, reached its maximum on May 9th and 12th, then declined, and was absent after June 12th. If the decrease in phosphates is to be attributed to their removal by algæ, as the writer considers to be the case, some other factor must be sought in addition to the phytoplankton. This is probably to be found in the larger algæ, such as *Fucus*, *Laminaria* and others. Well grown young plants of these are to be found in February, and must by that time have already abstracted considerable quantities of phosphorus from the water. The march of events would then be somewhat as follows. As soon as the young plants of the fixed algæ begin to increase the amount of phosphates in the water falls off, and this decline is further hastened by the sudden increase of diatoms at the end of April. In May the diatoms decrease, but the phosphates are kept at a minimum value by the appearance of *Phæocystis*, and increase at once when this disappears in June. The want of data for phosphates in July and August prevents a further comparison with the figures for diatoms, but another minimum might be expected in August. Phosphate values are also missing in November and December, 1916, but the records for 1915 show an agreement with what might be expected from the diatom figures, that is, a rise from November to December.

---

* Lebour, Marie V., M.Sc., "The Microplankton of Plymouth Sound from the Region beyond the Breakwater." This Journal and Volume, p. 133.

On January 10th, 1917, the amount of phosphates present was very nearly the mean of the first two figures for the month in the previous year.

The Admiralty regulations have made it impossible to obtain water at a distance from the shore. It is by no means improbable that in mid-Channel, beyond the influence of the fixed weeds, the decrease in the phosphates would not be large until much later in the year when the phytoplankton begins to increase.

The last column of the table contains some figures for the total dissolved phosphorus, calculated to P_2O_5. It is not claimed that they are accurate, but they certainly show that what may be called for the present "organic phosphorus" is often high even when the phosphates are at a minimum, though it varies from month to month. The figures for June 27th, 1916, and January 10th, 1917, are probably the most accurate, and as the two samples were analysed side by side they are fairly comparable. They show that the total phosphorus may be as high in summer as in winter, but that in summer only a very small part of it may be present as phosphoric acid. The analyses as a whole, however, do not allow more to be stated with certainty than that there is a soluble phosphorus compound present other than phosphoric acid, that it is probably not a lower acid of phosphorus owing to the comparative difficulty with which it is oxidised, and that it is probably an organic compound.

The nature and origin of this " organic phosphorus " is, of course, quite unknown. At first it was thought that it might be due to minute organisms which pass through a filter paper, and an attempt was made to filter it out by means of candles such as are used for bacteriological work, but this proved impossible as both Doulton and Chamberland filters gave up a considerable amount of phosphates to distilled water passed through them. It is, however, unlikely that it is due to solid particles, as if iron and a relatively large amount of ammonia are added to sea-water so as to produce a bulky precipitate of hydrates of iron, lime, and magnesium, which would almost certainly entangle and stop any suspended matter, the filtrate from this still shows a considerable amount of phosphate after oxidising.

SUMMARY.

The amount of phosphoric acid in sea-water off Plymouth was at a maximum of 0·06 mg. per litre of P_2O_5 at the end of December, 1915, after which it fell irregularly to a minimum of less than 0·01 mg., which extended from the last week of April to the latter part of May; it then increased again and in January, 1917, reached the same value as the average for the first part of the month in the previous year.

This seasonal variation is probably to be attributed to the removal of the phosphates from solution, at first by the fixed algæ, and later in the spring by the diatoms and for a short time by *Phæocystis*. There is also present in sea-water taken near Plymouth another soluble compound of phosphorus which can be converted into phosphoric acid by oxidising agents.

Abstract of Memoir

RECORDING WORK DONE AT THE PLYMOUTH LABORATORY.

The Development of Alcyonium Digitatum, with some notes on the Early Colony Formation. By Annie Matthews, M.Sc.

Quart. Journ. Micr. Sci., Vol. 62, *Part* 1, *New Series*, 1916.

THE above paper is a record of the successful rearing of Alcyonium larvæ in tanks at the Plymouth Laboratory.

Ripe male and female specimens collected near the Eddystone during the breeding seasons of 1912–13 and 1913–14 spawned in the tank water, and fertilised eggs were collected from which eventually young colonies were obtained.

Segmentation gave rise in various ways to a morula, followed by the pre-planula and planula stages. The pear-shaped free-swimming planula eventually settled by the broad anterior end, and the mouth arose at the narrow posterior end subsequent to a general flattening of the settled planula along the long axis.

The characteristic eight mesenteries grew out into the cœlenteron on the second day of fixation, followed by the appearance of spicules and eight hollow circumoral tentacles which alternated in position with the mesenteries. Free entrance of food was permitted on the fourth day, after the degeneration of the base of the œsophageal invagination. On the fifth and sixth day of fixation respectively the ventral and dorsal mesenteric filaments were formed, the two being of homogeneous origin, i.e. consisting of endodermic and ectodermic portions developed in different degrees.

At the end of the third week the first bud grew as an outgrowth from the basal stolon formed by the solitary polyp.

Very young fixed stages were fed with fine plankton, but colonies of two or three individuals or more were successfully fed on larvæ and single adults from Leptoclinum and Botryllus colonies. The early buds are arranged in circles round the parent, but in colonies of thirty-two individuals budding took place irregularly.

A. M.

Marine Biological Association of the United Kingdom.

Report of the Council, 1915.

The Council and Officers.

FOUR ordinary meetings of the Council were held during the year, at which the average attendance was nine. During the Easter Vacation a Committee of the Council visited and inspected the Laboratory at Plymouth.

The Association has suffered a great loss during the year through the death of Mr. J. A. Travers, who was for eighteen years its Honorary Treasurer. During his term of office Mr. Travers worked hard in the interests of the Association, and his advocacy of the practical value of the scientific fishery work which was being undertaken did much to ensure the continued progress of our investigations.

The Council elected Mr. George Evans, lately Prime Warden of the Worshipful Company of Fishmongers, to succeed Mr. Travers as Honorary Treasurer.

The Council desires to express its thanks to the Royal Society for the use of the Rooms at Burlington House in which its meetings have been held.

The Plymouth Laboratory.

The buildings, fittings and machinery at Plymouth have been kept in a state of efficient repair, but owing to the war all expenditure has been kept at the lowest possible limit. It has been necessary, however, to effect some repairs to the Shone's ejector, which pumps water from the sea, and the small gas-engine used for circulating sea-water through the Aquarium and Laboratory tanks has been fitted with a new piston and cylinder liner.

The Boats.

The steamer *Oithona* has not been put in commission this year. All the collecting work which has been possible has been done with the small sailing boat built for the Association two years ago. The motor boat given to us by Colonel G. M. Giles was sold early in the year for the sum of £35, as there was little prospect of making use of her for some time to come.

The Staff.

Dr. J. H. Orton and Mr. L. R. Crawshay have joined His Majesty's Forces for the war, making with Mr. E. W. Nelson and Mr. E. Ford, who joined last year, and Mr. R. S. Clark, who accompanied Sir Ernest Shackleton's Antarctic Expedition, five members of the staff who have been absent this year. Of the old staff, in addition to the Director, Dr. E. J. Allen, only Mr. D. J. Matthews remains, he being employed by the Association for half his time.

Miss M. V. Lebour, M.Sc., lecturer in Zoology of the University of Leeds, has been appointed a temporary Naturalist for the period of the war and the Council is indebted to the Senate of the University for granting Miss Lebour the necessary leave of absence. Mrs. D. J. Matthews, M.Sc., has also been engaged for part of her time in carrying out fishery researches for the Association.

Mr. D. W. Cutler, B.A., now Lecturer in Zoology at Manchester University, was employed for some months last summer in assisting with fishery work.

Those members of the staff who have joined His Majesty's Forces are being paid by the Association the differences between their salaries and service pay.

Occupation of Tables.

The following Naturalists have occupied tables at the Plymouth Laboratory during the year :—

W. De Morgan, Plymouth (Protozoa).
Dr. E. S. Goodrich, F.R.S., Oxford (Myxosporidia).
Mrs. Goodrich, B.SC., Oxford (Parasitic Protozoa).
Miss M. Irwin, B.A., Cambridge (Embryology of Elasmobranchs).
W. O. R. King, M.A., Leeds, Ray Lankester Investigator (Temperature coefficient of development of *Echinus miliaris*).
Mrs. W. O. R. King, Leeds (Enzymes of Echinoderm gonads).
D. G. Lillie, B.A., Cambridge (Antarctic Plankton).
J. H. Lloyd, Birmingham (Larvæ of Nematode of the Common Dogfish in *Carcinus mœnas*).
Mrs. Matthews, M.SC., Plymouth (Development of Alcyonium).
Mrs. E. W. Sexton, Plymouth (Amphipoda and Polychæta).
Dr. C. Shearer, M.A., Cambridge (Dinophilus).

The usual Easter Vacation Course in Marine Biology for University students was not held this year.

General Work at the Plymouth Laboratory.

The number of the Journal issued during the year (Volume X, No. 4) contains a report by Mr. L. R. Crawshay upon his experiments in the keeping of Plankton animals under artificial conditions. Since this paper was written Mr. Crawshay has, after a careful study of the different factors involved, succeeded in rearing *Calanus finmarchicus*, one of the most typical of the Plankton Copepods, through all stages from the egg to the adult form, under critical experimental conditions.

In the same number of the Journal the Director has published a revised list of the Polychæta of the Plymouth District and of the South Devon Coast, with records of the localities in which these annelids have been found. The list contains many new records for the English Channel and several for the British area.

The Director has been engaged for a portion of the year in examining a large collection of larval and young stages of fishes made by Mr. Clark and Mr. Ford in the summer of 1914, by the use of Petersen's young-fish trawl. This work will form the subject of a report on similar lines to those followed by Mr. Clark in his account in the Journal of the young-fish collections of 1913.

In connection with a scheme drawn up by the Board of Agriculture and Fisheries for the study of the different races of herrings found around the British coasts, Dr. Orton, with the help of a number of other workers, has examined two large samples of the Plymouth winter herrings, each containing over 500 fishes. This investigation involved the measurement and enumeration of some eighteen characters on each fish. The figures have been sent to the Board of Agriculture and Fisheries for comparison with those obtained from other localities, and in order to make them generally available they are also being published in the Journal of the Association.

A series of experiments has been commenced by Mr. D. W. Cutler, with a view to studying the growth of the scales of fishes kept in the Laboratory tanks under different conditions, especially as regards temperature. It is hoped that these experiments may throw some light upon the causes which produce the differences in the lines or markings on the scales now generally used in determining the age of fishes. Mrs. Matthews has taken charge of an investigation on the nutrition and growth-rate of fishes living under Aquarium conditions.

Mr. Matthews has been making determinations of the phosphates in samples of sea-water collected at about intervals of one week outside Plymouth Breakwater, in order to study seasonal changes. A considerable number of analyses have been made, and the results will be published in the next number of the Journal. The hydrographic work he was previously doing for the Fisheries Branch of the Department of Agriculture, etc. (Ireland), is in abeyance for the present, and since the latter part of October last he has been assisting in the chemical side of the investigations into cerebro-spinal meningitis which are being carried out at the Military Hospital at Stonehouse. The chemical work has been done in the Laboratory of the Association.

Miss M. V. Lebour has taken up the study of Plankton, especially that of the most minute organisms which escape from the ordinary silk tow-nets, but can be obtained by centrifuging samples of sea-water. The samples examined have been taken at frequent and regular intervals during the year by means of a water-bottle, which has been worked at several different depths, generally near the surface, about mid-water and near the bottom, at the entrance to Plymouth Sound. A numerical estimate has been made of the number of organisms of each kind in the individual samples. Miss Lebour has also undertaken the examination of a series of samples obtained by means of tow-nets during the last few years, at fortnightly intervals, at the Seven Stones Light Vessel, midway between Land's End and the Scilly Islands.

Mr. W. O. R. King, assisted by Mrs. King, spent some time at the Laboratory as Ray Lankester Investigator, and continued his work on the temperature coefficient of development of *Echinus*.

Mrs. E. W. Sexton has completed a paper on the Mendelian inheritance of eye-colour in the Amphipod, *Gammarus chevreuxi*, which is being published in the next number of the Journal.

Published Memoirs.

The following papers, either wholly or in part the outcome of work done at the Laboratory, have been published elsewhere than in the Journal of the Association :—

Drury, A. N. *The Eosinophil Cell of Teleostean Fish.* Journ. Physiology, vol. 49, 1915, pp. 349–366.

Gray, J. *Note on the Relation of Spermatozoa to Electrolytes and its bearing on the Problem of Fertilization.* Quart. Journ. Micr. Sci., vol. 61, 1915, pp. 119–126.

Orton, J. H. *An American Enemy of the English Oyster Farmer.* Trans. Plymouth Inst., vol. 15, 1912–13 (1915), pp. 247–261.

Pixell-Goodrich, H. L. M. *On the Life-History of the Sporozoa of Spatangoids, with Observations on some Allied Forms.* Quart. Journ. Micr. Sci., vol. 61, 1915, pp. 81–104.

Pixell-Goodrich, H. L. M., *Minchinia: A Haplosporidian.* Proc. Zool. Soc., 1915, pp. 445–457.

Potts, F. A. *Polychæta from the North-East Pacific: The Chætopteridæ. With an Account of the Phenomenon of Asexual Reproduction in Phyllochætopterus and the Description of Two New Species of Chætopteridæ from the Atlantic.* Proc. Zool. Soc., 1914, pp. 955–994.

Svedelius, N. *Zytologisch-Entwicklungsgeschichtliche Studien über Scinaia furcellata. Ein Beitrag zur Frage der Reduktionsteilung der nicht Tetrasporenbildenden Florideen.* Nova Acta Reg. Soc. Sc. Ups., Ser. iv., vol. 4, no. 4, 1915.

The Library.

The thanks of the Association are due to numerous Government Departments, Universities and other institutions at home and abroad for copies of books and current numbers of periodicals presented to the Library. The list is similar to that published in the Reports of Council of former years. A number of authors have been good enough to send reprints of their papers for the Library and to these also thanks are due.

Donations and Receipts.

The receipts for the year include a grant from H.M. Treasury of £500, being on account of the war one-half of the sum granted in recent years, a grant from the Board of Agriculture and Fisheries, Development Fund (£500), and one from the Fishmongers' Company (£600). In addition to these grants there have been received Annual Subscriptions (£136), Composition Fee (£15), Rent of Tables in the Laboratory, including £25 from the University of London and £20 from the Trustees of the Ray Lankester Fund (£19); Sale of Specimens (£324) and Admission to Tank Room (£99).

Vice-Presidents, Officers, and Council.

The following is the list of gentlemen proposed by the Council for election for the year 1916–17 :—

President.

Sir E. Ray Lankester, K.C.B., LL.D., F.R.S.

Vice-Presidents.

The Duke of Bedford, K.G
The Earl of Ducie, F.R.S.
The Earl of Stradbroke, C.V.O., C.B.
Lord Montagu of Beaulieu.
Lord Walsingham, F.R.S.
The Right Hon. A. J. Balfour, M.P., F.R.S.
The Right Hon. Austen Chamberlain, M.P.
W. Astor, Esq., M.P.
G. A. Boulenger, Esq., F.R.S.
A. R. Steel-Maitland, Esq., M.P.
Rev. Canon Norman, D.C.L., F.R.S.
Edwin Waterhouse, Esq.

Members of Council.

E. T. Browne, Esq.
L. W. Byrne, Esq.
Prof. H. J. Fleure, D.Sc.
E. S. Goodrich, Esq., D.Sc., F.R.S.
Sir Eustace Gurney.
Prof. J. P. Hill, D.Sc., F.R.S.
E. W. L. Holt, Esq.
H. G. Maurice, Esq., C.B.
Dr. P. Chalmers Mitchell, F.R.S.
C. C. Morley, Esq.
F. A. Potts, Esq.
C. Tate Regan, Esq.
Prof. D'Arcy W. Thompson, C.B.

Chairman of Council.

A. E. Shipley, Esq., D.Sc., F.R.S.

Hon. Treasurer.

George Evans, Esq., 1 Wood Street, London, E.C.

Hon. Secretary.

E. J. Allen, Esq., D.Sc., F.R.S., The Laboratory, Citadel Hill, Plymouth.

The following Governors are also members of the Council:—

G. P. Bidder, Esq., Sc.D.
W. P. Haskett Smith, Esq. (Prime Warden of the Fishmongers' Co.).
The Earl of Portsmouth (Fishmongers' Company).
Sir Richard Martin, Bart (Fishmongers' Company).
The Hon. Nathaniel Charles Rothschild (Fishmongers' Company).
George Evans, Esq. (Fishmongers Company).
Prof. G. C. Bourne, D.Sc., F.R.S. (Oxford University).
A. E. Shipley, Esq., D.Sc., F.R.S. (Cambridge University).
Prof. W. A. Herdman, D.Sc. F.R.S. (British Association).

THE MARINE BIOLOGICAL ASSOCIATION

Dr. *Statement of Receipts and Payments for*

	£	s.	d.	£	s.	d.
To Balance from Last Year:—						
Cash at Bankers	720	14	3			
Cash in hand	13	10	11	734	5	2
,, Current Receipts:—						
H.M. Treasury for the year ending 31st March, 1916	500	0	0			
The Worshipful Company of Fishmongers	600	0	0			
Annual Subscriptions	135	8	0			
Rent of Tables (including Ray Lankester's Trustees, £20; University of London, £25)	48	15	0			
Interest on Investments	14	11	0	1,298	14	0
,, Extraordinary Receipts:—						
Donation, G. H. Fox	0	10	6			
Composition Fee	15	15	0			
Board of Agriculture and Fisheries, Grant from Development Fund for year ending 31st March, 1916	500	0	0	516	5	6
,, Laboratory Boats and Sundry Receipts:—						
Sales of Apparatus	7	19	0			
,, ,, Specimens	323	14	1			
,, ,, Boats, Nets, Gear, etc.	55	7	2			
Rebate of Insurance, S.Y. "Oithona"	20	13	1			
Other Items	1	1	0	408	14	4

The Association's Bankers hold on its behalf £410 14s. 8d. New Zealand 4% Stock, 1943–63.

	£2,957	19	0

OF THE UNITED KINGDOM.

the Year ending 31*st December*, 1915. Cr.

	£	s.	d.	£	s.	d.
By Salaries and Wages—						
Director	300	0	0			
Hydrographer	150	0	0			
Senior Naturalist	91	9	4			
Additional ,,	138	14	2			
Temporary ,,	97	11	9			
Assistant ,,	61	0	10			
,, ,, (temporary)	52	9	6			
Salaries and Wages	479	2	7	1,370	8	2
,, Travelling Expenses				14	0	3
,, Library	84	4	2			
Less Duplicates sold	0	19	0	83	5	2
,, Journal	107	6	9			
Less Sales	17	16	1	89	10	8
,, Buildings and Public Tank Room—						
Gas, Water, and Coal	147	16	4			
Stocking Tanks and Feeding	33	2	11			
Maintenance and Renewals	156	8	11			
Rent, Rates, Taxes, and Insurance	46	14	0			
	384	2	2			
Less Admission to Tank Room, etc.	107	13	1	276	9	1
,, Laboratory, Boats, and Sundry Expenses—						
Glass, Apparatus, and Chemicals	75	0	2			
Purchase of Specimens	31	16	10			
Maintenance and Renewals of Boats, Nets, etc.	41	5	8			
Boat Hire and Collecting Expeditions	10	16	5			
Insurance of S.Y. "Oithona"	5	19	11			
Coal and Water for Steamer	1	16	0			
Stationery, Office Expenses, Carriage, Printing, etc.	87	17	8	254	12	8
,, Balance :—						
Cash at Bankers	852	0	2			
Cash in hand	17	12	10	869	13	0
				£2,957	19	0

Examined and found correct,

28*th January*, 1916.

(Signed) N. E. Waterhouse.
Edward T. Browne.
J. O. Borley.

Marine Biological Association of the United Kingdom.

LIST
OF
Governors, Founders, and Members.

1st May, 1917.

* Member of Council. † Vice-President. ‡ President.

Ann. signifies that the Member is liable to an Annual Subscription of One Guinea.

C. signifies that he has paid a Composition Fee of Fifteen Guineas in lieu of Annual Subscription.

I.—Governors.

The British Association for the Advancement of Science, *Burlington House, W.*	£500
The University of Oxford	£500
The University of Cambridge	£500
The Worshipful Company of Clothworkers, 41, *Mincing Lane, E.C.*	£500
The Worshipful Company of Fishmongers, *London Bridge, E.C.*	£12,505
Bayly, Robert (the late)	£1000
Bayly, John (the late)	£600
Thomasson, J. P. (the late)	£970
G. P. Bidder, Esq., Sc.D., *Cavendish Corner, Cambridge*	£1500

II.—Founders.

1884	The Corporation of the City of London	£210
1884	The Worshipful Company of Mercers, *Mercers' Hall, Cheapside*	£341 5s.
1884	The Worshipful Company of Goldsmiths, *Goldsmiths' Hall, E.C.*	£100
1884	The Royal Microscopical Society, 20, *Hanover Square, W.*	£100
1884	The Royal Society, *Burlington House, Piccadilly, W.*	£350
1884	The Zoological Society, *Regent's Park, London, N.W.*	£100
1884	Bulteel, Thos. (the late)	£100
1884	Burdett-Coutts, W. L. A. Bartlett, 1, *Stratton Street, Piccadilly, W.*	£100
1884	Crisp, Sir Frank, Bart., Treas. Linn. Soc., 17, *Throgmorton Avenue, E.C.*	£100
1884	Daubeny, Captain Giles A.	£100
1884	Eddy, J. Ray, *The Grange, Carleton, Skipton*	£100
1884	Gassiott, John P. (the late)	£100
‡1884	Lankester, Sir E. Ray, K.C.B., F.R.S., 29, *Thurloe Place, South Kensington, S.W.*	£100

1884	The Rt. Hon. Lord Masham (the late)	£100
1884	Moseley, Prof. H. N., F.R.S. (the late)	£100
1884	The Rt. Hon. Lord Avebury, F.R.S. (the late)	£100
1884	Poulton, Prof. Edward B., M.A., F.R.S., *Wykeham House, Oxford*	£100
1884	Romanes, G. J., LL.D., F.R.S. (the late)	£100
1884	Worthington, James (the late)	£100
1885	Derby, the late Earl of	£100
1887	Weldon, Prof. W. F. R., F.R.S. (the late)	£100
1888	Bury, Henry, M.A., *Mayfield House, Farnham, Surrey*	£100
1888	The Worshipful Company of Drapers, *Drapers' Hall, E.C.*	£315
1889	The Worshipful Company of Grocers, *Poultry, E.C.*	£120
1889	Thompson, Sir Henry, Bart. (the late)	£110
1889	Revelstoke, The late Lord	£100
1890	Riches, T. H., B.A., *Kitwells, Shenley, Herts*	£230
1902	Gurney, Robert, *Ingham Old Hall, Stalham, Norfolk*	£105
1909	Harding, Colonel W., *The Hall, Madingley, Cambridge*	£100
1910	Murray, Sir John, K.C.B., F.R.S. (the late)	£100
1912	Swithinbank, H., F.R.S.E., F.R.G.S., *Denham Court, Denham, Bucks.*	£100
1913	Shearer, Dr. Cresswell, 30, *Thompson's Lane, Cambridge*	£100

III.—Members.

1913	Adams, Alfred, M.B., B.Ch., Oxon., *Looe, Cornwall*	Ann.
1897	Adams, W. R., 11, *Windsor Road, Denmark Hill, Camberwell, London, S.E.*	Ann.
1900	Aders, Dr. W. M., *Zanzibar, East Africa*	Ann.
*1895	Allen, E. J., D.Sc., F.R.S., *The Laboratory, Plymouth*	Ann.
1889	Alward, G. L., *Enfield Villa, Humberstone Avenue, Waltham, Grimsby*	Ann.
1910	Ashworth, J. H., D.Sc., *The University, Edinburgh*	Ann
†1911	Astor, W., M.P., 4, *St. James's Square, London, W.*	C.
1910	Atkinson, G. T., 43, *Parliament Street, London, S.W.*	Ann.

1902	Baker, R. J., 89, *Alexandra Road, Plymouth*	Ann.
1884	Balfour, Prof. Bayley, F.R.S., *Royal Botanic Gardens, Edinburgh*	C.
*1884	Bayliss, Prof. W. Maddock, D.Sc., F.R.S., *St. Cuthberts, West Heath Road, Hampstead*	Ann.
1884	Bayly, Miss Anna, *Seven Trees, Plymouth*	£50
1885	Beck, Conrad, 68, *Cornhill, E.C.*	C.
1884	Beddington, Alfred H., 8, *Cornwall Terrace, Regent's Park, N.W.*	C.
†1907	Bedford, His Grace the Duke of, K.G., *Endsleigh, Tavistock*	C.
1903	Bidder, Major H. F., *Ravensbury Manor, Mitcham*	Ann.
1910	Bidder, Mrs. M. G., *Cavendish Corner, Cambridge*	Ann.
1912	Bles, E. J., D.Sc., *Elterholm, Madingley Road, Cambridge*	Ann.
1910	Bloomer, H. H., 40, *Bennett's Hill, Birmingham*	Ann.
1910	Borley, J. O., M.A., 43, *Parliament Street, London, S.W.*	Ann.
*1884	Bourne, Prof. Gilbert C., M.A., F.R.S., *Savile House, Mansfield Road, Oxford*	Ann
1898	Bowles, Col. Henry, *Forty Hall, Enfield*	Ann
1910	Bradford, Sir J. Rose, K.C.M.G., M.D., D.Sc., F.R.S., 8, *Manchester Square, London, W.*	Ann.

1902	Brighton Public Library (Henry D. Roberts, Chief Librarian)	Ann.
1886	Brooksbank, Mrs. M., *Leigh Place, Godstone, Surrey*	*C.*
1884	Brown, Arthur W. W., 62, *Carlisle Mansions, Carlisle Place, London, S.W.*	*C.*
*1893	Browne, Edward T., B.A., *Anglefield, Berkhamsted*	Ann.
1892	Browne, Mrs. E. T., *Anglefield, Berkhamsted*	Ann.
*1897	Byrne, L. W., B.A., 7, *New Square, Lincoln's Inn, London, W.C.*	Ann.

1908	Calman, Dr. W. T., *British Museum (Natural History), Cromwell Road, S.W.*	Ann.
1912	Cavers, Dr. F., *Goldsmiths' College, New Cross, London, S.E.*	Ann.
1913	Childs, Christopher, M.D., *Boscarne, Looe*	Ann.
1911	Chilton, Prof. C., *Canterbury College, Christchurch, New Zealand*	Ann.
1884	Christy, Thomas Howard	*C.*
1911	Clark, Dr. J., *Technical School, Kilmarnock, N.B.*	Ann.
1910	Clarke, G. S. R. Kitson, *Meanwoodside, Leeds*	Ann.
1887	Clarke, Rt. Hon. Sir E., K.C., 5, *Essex Court, Temple, E.C.*	£25
1886	Coates and Co., *Southside Street, Plymouth*	*C.*
1885	Collier Bros., *George Street, Plymouth*	*C.*
1912	Cotton, A. D., *The Herbarium, Royal Gardens, Kew*	Ann.
1909	Crawshay, L. R., M.A., *The Laboratory, Plymouth*	Ann.

1916	Delphy, J., *Laboratoire Maritime de Tatihou, par St. Vaast-la-Hougue (Manche), France*	Ann.
1885	Darwin, Sir Francis, F.R.S., 10, *Madingley Road, Cambridge*	*C.*
*1906	De Morgan, W. C., *c/o National Provincial Bank, Plymouth*	Ann.
1908	Dendy, Prof. A., F.R.S., *Vale Lodge, Hampstead Heath, N.W.*	Ann.
1884	Dewick, Rev. E. S., M.A., F.G.S., 26, *Oxford Square, Hyde Park, W.*	*C.*
1915	Dick, G. W., J.P., c/o P.O. Box 28, *The Point, Durban, Natal*	*C.*
1915	Director of Agriculture and Fisheries, *Travancore, Quilon, S. India*	Ann.
1885	Dixey, F. A., M.A. Oxon., F.R.S., *Wadham College, Oxford*	£26 5*s. and* Ann.
1910	Dobell, C. C., M.A., *Imperial College of Science and Technology, South Kensington, S.W.*	Ann.
1890	Driesch, Hans, Ph.D., *Philosophenweg* 5, *Heidelberg, Germany*	*C.*
†1889	Ducie, The Rt. Hon. the Earl of, F.R.S., *Tortworth Court, Falfield, R.S.O.*	£50 15*s.*
1910	Duncan, F. Martin, 71, *St. Leonard's Road, East Sheen, S.W.*	Ann.
1884	Dunning, J. W., 4, *Talbot Square, London, W.*	£26 5*s.*
1884	Dyer, Sir W. T. Thiselton, M.A., K.C.M.G., F.R.S., *The Ferns, Witcombe, Gloucester*	*C.*

1908	Elwes, Maj. Ernest V., c/o Hon. Secretary, *Torquay Natural History Society, The Museum, Torquay*	Ann.
1885	Ewart, Prof. J. Cossar, M.D., F.R.S., *University, Edinburgh*	£25

1894	Ferrier, Sir David, M.A., M.D., F.R.S., 34, *Cavendish Square, W.*	Ann.
1884	Fison, Sir Frederick W., Bart., *Boarzell, Hurst Green, Sussex*	*C.*
*1913	Fleure, Prof. H. J., D.Sc., *University College of Wales, Aberystwyth*	Ann.
1897	Foster, Richard, *Windsworth, Looe, R.S.O.*	Ann.
1885	Fowler, G. Herbert, B.A., Ph.D., *The Old House, Aspley Guise, Bedfordshire*	Ann.
1884	Fry, George, F.L.S., *Carlin Brae, Berwick-on-Tweed*	£21

1912	Fuchs, H. M. de F., *Zoological Department, Imperial College of Science and Technology, South Kensington, S.W.*	Ann.
1907	Gamble, Prof. F. W., D.Sc., F.R.S., *The University, Edmund Street, Birmingham*	Ann.
1906	Gardiner, Prof. J. Stanley, M.A., F.R.S., *Caius College, Cambridge*	Ann.
1907	Garstang, Prof. W., D.Sc., 2, *Ridge Mount, Cliff Road, Headingley, Leeds*	Ann.
1910	Gooding, H. C., *Ipswich Street, Stowmarket*	Ann.
*1910	Goodrich, E. S., F.R.S., *Merton College, Oxford*	Ann.
1885	Gordon, Rev. J. M., 7, *Moreton Gardens, London, S.W.*	Ann.
1912	Gray, J., *King's College, Cambridge*	Ann.
1899	Guinness, Hon. Rupert, *Elveden, Thetford*	£35 15*s.*
1916	Guitel, Prof. F., *Laboratoire de Zoologie, Rennes, France*	Ann.
1900	Gurney, Sir Eustace, *Sprowston Hall, Norwich*	Ann.
1884	Halliburton, Prof. W. D., M.D., F.R.S., *Church Cottage*, 17, *Marylebone Road, London, W.*	Ann.
1884	Hannah, Robert, 82, *Addison Road, Kensington, W.*	*C.*
1885	Harmer, S. F., D.Sc., F.R.S., *British Museum (Natural History), Cromwell Road, S.W.*	*C.*
1888	Haselwood, J. E., 3, *Richmond Terrace, Brighton*	*C.*
1884	Haslam, Miss E. Rosa, *Ravenswood, Bolton*	£20
1884	Head, J. Merrick, F.R.G.S., J.P., *Pennsylvania Castle, Isle of Portland, Dorset*	Ann.
1884	Heape, Walter, F.R.S., 10, *King's Bench Walk, Temple, London, E.C.*	*C.*
1910	Hefford, A. E., B.Sc., *Riggside, Sandend, Whitby, Yorks*	Ann.
1908	Hepworth, Commander M. W. Campbell, C.B., R.N.R., *Meteorological Office, South Kensington, London, S.W.*	Ann.
*1884	Herdman, Prof. W. A., F.R.S., *The Zoology Department, The University, Liverpool*	Ann.
1913	Heron-Allen, E., F.L.S., F.R.M.S., F.G.S., 33, *Hamilton Terrace, London, N.W.*	*C.*
1884	Herschel, Col. J., R.E., F.R.S., *Observatory House, Slough, Berks.*	*C.*
1910	Hicks, F., *Zoological Laboratory, King's College, London, W.C.*	Ann.
1884	Hickson, Prof. Sydney J., M.A., D.Sc., F.R.S., *Ellesmere House, Wilenslow Road, Withington, Manchester*	Ann.
1907	Hill, Prof. J. P., F.R.S., *The Zoological Laboratory, University College, London, W.C.*	Ann.
1897	Hodgson, T. V., *Highfield, Plympton, S. Devon*	Ann.
*1905	Holt, E. W. L., *Department of Agriculture and Technical Instruction for Ireland (Fisheries Branch), Dublin*	Ann.
1909	Hoyle, W. E., M.A., D.Sc., *National Museum of Wales, City Hall, Cardiff*	Ann.
1912	Huxley, Prof. J. S., *The Rice Institute, Houston, Texas, U.S.A.*	Ann.
1885	Jackson, W. Hatchett, M.A., D.Sc., F.L.S., *Pen Wartha, Weston-super-Mare*	Ann.
1914	James, Lewis H., 43, *Parliament Street, London, S.W.*	Ann.
1914	Jarvis, P. W., *Colonial Bank, Trinidad, and* 27, *Crescent Lane, London, S.W.*	Ann.
1911	Kirkpatrick, R., *British Museum (Natural History), Cromwell Road, S.W.*	Ann.

1897	Lanchester, W. F., B.A., 19, *Fernshaw Road, Chelsea, London, S.W.*	*C.*
1885	Langley, Prof. J. N., F.R.S., *Trinity College, Cambridge*	*C.*
1915	Lillie, D. G., B.A., *St. John's College, Cambridge*	Ann.
1895	Lister, J. J., M.A., F.R.S., *St. John's College, Cambridge*	Ann.
1910	Liversidge, Prof. A., F.R.S., *Fieldhead, George Road, Coombe Warren, Kingston, Surrey*	Ann.
1912	Lloyd, Miss D. Jordan, *The Mythe, Edgbaston, Birmingham*	Ann.
1885	Macalister, Prof. A., F.R.S., *St. John's College, Cambridge*	Ann.
*1910	MacBride, Prof. E. W., M.A., D.Sc., F.R.S., *Royal College of Science, South Kensington, S.W.*	Ann.
1900	Macfie, J. W. Scott, *Rowton Hall, Chester*	*C.*
1902	Major, Surgeon H. G. T., 24, *Beech House Road, Croydon*	*C.*
1889	Makovski, Stanislaus, *Saffrons Corner, Eastbourne*	Ann.
1885	Marr, J. E., M.A., F.R.S., *St. John's College, Cambridge*	*C.*
1906	Masterman, A. T., D.Sc., F.R.S., *Board of Agriculture and Fisheries (Fisheries Division)*, 43, *Parliament Street, London, S.W.*	Ann.
1910	Matthews, D. J., *c/o T. C. Matthews, Esq., Pitt White, Uplyme, S. Devon*	Ann.
1912	Matthews, Mrs. D. J., *c/o T. C. Matthews, Esq., Pitt White, Uplyme, S. Devon*	Ann.
*1912	Maurice, H. G., C.B., *Board of Agriculture and Fisheries*, 43, *Parliament Street, S.W.*	Ann.
1910	McClean, W. N., 1, *Onslow Gardens, London, S.W.*	Ann.
1884	McIntosh, Prof. W. C., F.R.S., 2, *Abbotsford Crescent, St. Andrews*	*C.*
1884	Michael, Albert D., *The Warren, Studland, nr. Wareham, Dorset*	*C.*
1909	Midgley, J. H., B.Sc., *Birstwith, Torquay*	Ann.
*1905	Mitchell, P. Chalmers, D.Sc., F.R.S., Secretary Zoological Society, *Regent's Park, London, N.W.*	Ann.
†1914	Montagu of Beaulieu, The Rt. Hon. Lord, 62, *Pall Mall, London.*	Ann., £2 2s.
1906	Morford, Rev. Augustin, *Syon Abbey, Chudleigh*	Ann.
*1915	Morley, C. C., c/o Messrs. Morley, Sellick and Price, Steam Trawler Owners, *Milford Haven*	Ann.
1912	Newman, C. A., *Bramston House, Oundle*	Ann.
†1884	Norman, Rev. A. M., M.A., D.C.L., F.R.S., *The Red House, Berkhamsted, Herts*	Ann.
1911	Oldham, Chas., *Kelvin, Boxwell Road, Berkhamsted, Herts.*	Ann.
1910	Orton, J. H., D.Sc., *The Laboratory, Plymouth*	Ann.
1915	Pascual, Enrique, P.O. Box 8, *Galicia, Vigo, Spain*	Ann.
1906	Plymouth Corporation (Museum Committee)	Ann.
1910	Plymouth Education Authority	Ann.
1906	Port of Plymouth Incorporated Chamber of Commerce	Ann.
1910	Porter, Horatio, 16, *Russell Square, London, W.C.*	Ann.
*1913	Potts, F. A., M.A., *Trinity Hall, Cambridge*	*C.*
1910	Preston, H. B., F.Z.S., 53, *West Cromwell Road, London, S.W.*	Ann.
1893	Quintin, St. W. H., *Scampstone Hall, Rillington, Yorks*	Ann.
1913	Raymond, Major G., *The Gymnasium, Western College Road, Plymouth*	Ann.
*1916	Regan, C. Tate, F.R.S., British Museum (Natural History), *Cromwell Road, S.W.*	Ann.

1914	Samuel, T. A. S., *North Hill House, Torpoint, Cornwall*	Ann.
1911	Saunders, J. T., B.A., *Christ's College, Cambridge*	Ann.
1914	Savage, R. E., *Board of Agriculture and Fisheries, Winchester House,* 21, *St. James's Square, London, S.W.*	Ann.
1888	Scharff, Robert F., Ph.D., *Science and Art Museum, Dublin*	Ann.
1901	Schiller, F. W., *Butterhill, Stafford*	Ann.
1909	Schuster, Edgar, D.Sc., 110, *Banbury Road, Oxford*	Ann.
1884	Sclater, W. L., 10, *Sloane Court, London, S.W.*	Ann.
1885	Scott, D. H., M.A., Ph.D., F.R.S., *East Oakley House, Oakley, Hants*	*C.*
1888	Serpell, E. W., *Loughtonhurst, West Cliff Gardens, Bournemouth*	£50
1900	Sexton, L. E., 3, *Queen Anne Terrace, Plymouth*	Ann.
1904	Shaw, Joseph, K.C., *Bryanston Square, London, W.*	£13
1885	Sheldon, Miss Lilian, *High Park, Bideford*	Ann.
*1884	Shipley, Arthur E., D.Sc., F.R.S., *Christ's College, Cambridge*	*C. and* Ann., £3 3s.
1891	Sinclair, William F., 102, *Cheyne Walk, Chelsea, S.W*	*C.*
1884	Skinners, the Worshipful Company of, *Skinners' Hall, E.C.*	£42
1889	Slade, Rear-Admiral Sir E. J. W., K.C.I.E., K.C.V.O., 128, *Church Street, Campden Hill, London, W.*	*C.*
1888	Spencer, Sir W. Baldwin, K.C.M.G., M.A., F.R.S., *University of Victoria, Melbourne*	Ann.
1907	Sprague, Thomas Bond, M.A., LL.D., *West Holme, Woldingham, Surrey*	Ann.
1897	Straker, J., LL.M., F.Z.S., *Oxford and Cambridge Club, S.W.*	*C.*
*1899	Thompson, Prof. D'Arcy W., C.B., F.R.S., *University College, Dundee*	Ann.
1890	Thompson, Sir H. F., Bart., 9, *Kensington Park Gardens, London, W.*	Ann.
1884	Thornycroft, Sir John I., F.R.S., *Eyot Villa, Chiswick Mall*	Ann.
1906	Tims, H. W. Marett, M.D., *Bedford College, Regent's Park, London, N.W.*	Ann.
1903	Torquay Natural History Society, *Torquay*	Ann.
1910	Travers, Miss R. C., *Tortington House, Arundel*	*C.*
1891	Vaughan, Henry	*C.*
1884	Walker, Alfred O., *Ulcombe Place, Maidstone*	Ann.
1884	Walker, P. F., 36, *Prince's Gardens, S.W.*	Ann.
1910	Wallace, W., D.Sc , 43, *Parliament Street, London, S.W.*	Ann.
†1884	Walsingham, The Rt. Hon. Lord, F.R.S., *Merton Hall, Thetford*	£20
1912	Ward, Dr. Francis, 20, *Park Road, Ipswich*	Ann.
1906	Waterhouse, N. E., 3, *Fredericks Place, Old Jewry, London, E.C.*	Ann.
1909	Waters, Arthur W., F.L.S., *Alderley, McKinley Road, Bournemouth*	Ann.
1909	Watson, A. T., *Southwold, Tapton Crescent Road, Sheffield*	Ann.
1906	Weldon, Mrs., *Merton Lea, Oxford*	Ann.
1910	Willes, W. A., *Elmwood, Cranborne Road, Bournemouth*	Ann.
1900	Willey, A., D.Sc., F.R.S., *McGill University, Montreal, Canada*	Ann.
1908	Williamson, Lieut. H. A., R.N., *Air Department, Admiralty, S.W.*	Ann.
1884	Wilson, Scott, B., *Heather Bank, Weybridge Heath*	*C.*
1913	Wise, W. H., 34, *George Street, Plymouth*	Ann.
1905	Woolf, M. Yeatman, *Wimpole House, Wimpole Street, London, W.*	Ann.
1898	Worth, R. H., 42, *George Street, Plymouth*	Ann.
1913	Warden of Fisheries, *Punjab, Upper Dharamsala, District Kangra, India*	Ann.

IV.—Associate Members.

1914 Dunn, Howard, *Mevagissey, Cornwall.*
1914 Dunn, Matthias, J.P., *Newlyn, Cornwall.*
1904 Edwards, W. C., *Mercantile Marine Office, St. Andrew's Dock, Hull.*
1904 Freeth, A. J., *Fish Quay, North Shields.*
1904 Hurrell, H. E., 25, *Regent Street, Yarmouth.*
1904 Inskip, H. E., Capt., R.N., *Harbour Master's Office, Ramsgate.*
1904 Johnson, A., *Fishmongers' Company, Billingsgate Market, London, E.C.*
1889 Olsen, O. T., F.L.S., F.R.G.S., *Fish Dock Road, Great Grimsby.*
1904 Patterson, Arthur, *Ibis House, Great Yarmouth.*
1889 Ridge, B. J., *Newlyn, Penzance.*
1901 Sanders, W. J., *Rockvall, Brixham.*
1889 Sinel, Joseph, 8, *Springfield Cottages, Springfield Road, Jersey, C.I.*
1890 Wells, W., *The Aquarium, Brighton.*

The Loss of the Eye-pigment in *Gammarus chevreuxi.*

A Mendelian Study.

By

E. J. Allen, D.Sc., F.R.S.,

Director of the Plymouth Laboratory,

AND

E. W. Sexton, F.L.S.

With Plates I to VII at the end.

CONTENTS.

PAGE
SECTION I. ALBINO IMPERFECT EYE 274
Cross A. Albino Female AC × Red Male R.2. Plate I 275
Cross B. Albino Female AC × Black Male K. A. 278
Constitution of Blacks II, III, IV and V 278
,, Reds II, III, IV and V 284
,, F_2 Albinos 286
SECTION II. ALL-WHITE PERFECT EYE 287
Cross C. Albino Female AB × White Male R.1. 287
Hypotheses I and II 288
Constitution of Blacks VI, Cross C 291
Cross-matings ,, ,, ,, ... 303
Constitution of Reds ,, ,, ... 307
,, Albinos ,, ,, ... 317
Experiments with the Original Stock 324
The Part-White Eye 325
SECTION III. NO-WHITE EYE. VII 326
SECTION IV. COLOURLESS EYE 330
Cross between Coloured No-white and Albino 330
Independent Origin of Coloured No-white and Albino No-white or Colourless eyes 336
Constitution of the Colourless eye 338
SECTION V. ONE-SIDED NO-WHITES 339
SUMMARY 341
GENERAL CONSIDERATIONS 348
EXPLANATION OF PLATES 350

IN a paper by Sexton and Wing (Journ. M.B.A., Vol. XI, No. 1, pp. 18–50) a mutation occurring in the Amphipod *Gammarus chevreuxi* Sexton, was described and figured (Pl. I, Fig. 3) in which the usual black pigment of the eye was replaced by a bright red pigment.* It was shown that these red eyes behaved as a pure recessive in accordance with Mendel's law, the hybrid between red-eyed and pure black-eyed animals being black. Certain other mutations which had just occurred were also described and figured in that paper, and it is to a study of these and of others that have since appeared that the present paper is due.

Our thanks are due to Miss A. R. Clark, who has given valuable help in the care of the broods and in the examination of the young animals for eye-colour.

The system employed for designating the different broods and the individual animals in each brood is as follows : The two original Albino females from which the experiments started are called AB and AC. The five broods obtained from AC are numbered I to V, the one brood from AB is numbered VI. Each animal which came to maturity in each of these broods is designated by a capital letter, A, B, C, etc. Each brood derived from one of these females is numbered by an arabic numeral, and each animal in the brood is denoted by a small letter, a, b, c, etc. Thus I.E.3.a. means the first individual (a) in the third brood (3), of female E from brood I of the original female AC. (See Plate I.)

In the plates the colour developed in the eye of each animal is shown by the large circles, and the constitution of the animal in regard to the factors for eye-colour, when known, by the character and position of the small circles. The V-shaped mark indicates that the presence or absence of the factor usually represented in the position where the mark stands has not been proved.

In the text the colours are represented by capital letters. A means albino, B black, R red and N no-white. The first letter in a formula in black type gives the visible colour of the eye, the remaining letters the constitutional factors which are carried. Thus **B**+R+A means a black-eyed animal, carrying the factors for red and albino, **B**+N means a black-eyed animal carrying the factor for no-white. **BN** and **RN** mean black and red no-white respectively.

SECTION I. THE ALBINO† IMPERFECT EYE.

The shape of the normal eye of *Gammarus chevreuxi* is reniform, with the margin entire. (Plate VII. Fig. 2.) The eye is raised above the surface of the cephalon, and much rounded, and is composed of numerous ommatidia arranged in regular rows, each ommatidium being surrounded by pigmented retinular cells, the pigment being black in the normal eye, red in the mutation. On the surface and around the upper portion of the ommatidia, a chalky white extra-retinal pigment is found, the "accessory pigment," which gives the reticulated appearance to the ommateum. In the albino eye only this extra-retinal pigment is developed. (Plate VII. Fig. 4.) The ommateum is much altered, is reduced considerably in size, and is very variable in shape, even the eyes of the same animal often differing widely in form, and in the size, shape, number and arrangement of the ommatidia. The surface of the eye is flat, not convex as in the type, with a few ommatidia sparsely scattered, generally around the margin, and with some occasionally lying beyond it. Especially portions of the extra-retinal chalk-white pigment tend to become detached, causing white spots to appear in more or less definite positions on the head. A more detailed study of these spots is still in progress.

---

* It may be mentioned here that no second case of a red-eyed Gammarus arising independently has occurred up to the present time (September, 1917), all the red-eyed animals used in the experiments being descendants of the original stock.

† The term "Albino" is here used to designate those animals in which the eye possesses no coloured retinal pigment, but in which the chalk-white extra-retinal pigment is present. For eyes in which the coloured retinal pigment and the chalk-white extra-retinal pigment are both absent we employ the term "colourless."

The Albino eye appeared in the F_2 generation from a mating of Pure Black with Pure Red. The young (F_1) of this mating all had normal black eyes. The 15 which survived to maturity were kept together in one bowl to breed, each female when ovigerous being removed to a separate bowl until her young were hatched, and then returned to the brood-bowl to mate again. The forty-second brood (F_2) obtained from this family consisted of 7 Black-eyed young, 1 Red-eyed and 4 with neither black nor red pigment, the Albino eye just described. The total number of young recorded from all the broods was 745, of which 559 were black-eyed, 182 red-eyed and 4 albino-eyed. The four albinos reached maturity, one male and three females, but only two females survived to produce offspring, the AB and AC (Plate II) of the following experiments.

All the albino-eyed animals used in the experiments are descendants of these, and there has been no other case observed of an independent origin of this mutation. The stock from which these two females came was kept for a further period of eighteen months, and no more albino eyes occurred in it.

Cross A.

CROSS BETWEEN THE ALBINO FEMALE AC AND A PURE RED MALE R.2. (Plate I.)

One of these females (AC) was mated with a male from Pure Red stock (R.2), the resulting offspring being 3 black and 6 red-eyed young. This at once suggests that colour is dominant to absence of colour, and that the albino eye, in which only white accessory pigment appeared, contained the factors for both black and red retinal pigment.

Following Bateson and Punnett we may assume a colour factor C, which with its absence c forms an allelomorphic pair. In the absence of C the factors for black and red in the retinal pigment do not produce any visible effect. The constitution of the pure red male would then be $\frac{\text{C R}}{\text{C R}}$ and of the albino female $\frac{\text{c B}}{\text{c R}}$ where B and R are the factors for black and red respectively.

The mating of these should give in F_1 :—

C c B R, a black carrying the factor for "red" and also the factor for "albino";*

C c R R, a pure red carrying the factor for "albino."

*F.*1. *Generation. Black* × *Black.*

The three black-eyed young of this F_1 generation were 2 females and 1 male (Pl. I: I.A.B.C.). The male was mated with the females in turn and three broods were obtained from each. The total number of young was 119, of which 61 were black-eyed, 28 red-eyed, and 30 albino-eyed.

Theoretically the cross

C c B R × C c B R

gives gametes C B
C R
c B
c R

which with chance meetings would give zygotes :—

C B C B	C B C R	C B c B	C B c R
C R C B	C R C R	C R c B	C R c R
c B C B	c B C R	c B c B	c B c R
c R C B	c R C R	c R c B	c R c R

That is out of every 16 young there are 9 Black-eyed, viz. :—

1 with constitution C C B B
2 ,, ,, C c B B
2 ,, ,, C C B R
4 ,, ,, C c B R

---

* We shall for convenience refer to the factor *c*, which on the hypothesis represents the absence of the colour factor C, as the "albino factor."

3 Red-eyed, viz. :—

1 with constitution C C R R
2 ,, ,, C c R R

4 Albinos, viz. :—

1 with constitution c c B B
1 ,, ,, c c R R
2 ,, ,, c c B R

For 119 specimens the numbers should be according to theory
67 black, 22 red, 30 albino,
whilst those found by experiment were 61 black, 28 red, 30 albino,
a sufficiently close agreement.

*F.*1. *Generation. Red × Red.*

The six red-eyed young of the F_1 generation were 4 females and 2 males (Plate I : I.D.E.F.G.H.J.). The males were mated with the females and 875 young were obtained, including a brood of 17 not examined within 48 hours of extrusion.*

According to theory the parents all had the constitution CcRR, and these mated together should give :—

3 Red-eyed, viz. :—

1 with constitution C C R R
2 ,, ,, C c R R
1 Albino ,, ,, c c R R

Experiment gave 658 red-eyed and 217 albino,† theory requires 656 red-eyed and 219 albino.

*F.*1. *Generation. Black × Red.*

A cross between a red-eyed female and black-eyed male of the F_1 generation (Pl. I : I.B. and D.) gave in three broods 9 black-eyed, 15 red-eyed and 8 albino. Theory requires the proportions 3 black, 3 red, 2 albino, which for 32 young would be 12 black, 12 red, 8 albino.

---

* Unless the young are examined and removed soon after they are extruded a certain number are lost through being eaten by the parents and the more delicate ones tend to disappear first. The albinos seem to be more delicate than the reds, and the reds than the blacks, so that unless the broods are counted within a short time the proportions of the different coloured eyes are liable to error. THE FIGURES GIVEN IN THE PRESENT PAPER INCLUDE ONLY SUCH BROODS AS WERE COUNTED WITHIN FORTY-EIGHT HOURS OF THE TIME OF EXTRUSION, UNLESS THE CONTRARY IS DEFINITELY STATED.

† Of these 589 red-eyed and 191 albinos came from the mating of one pair. (I.F. × I.E. Plate I, see p. 336).

Cross B.

CROSS BETWEEN THE ALBINO FEMALE AC. AND BLACK HYBRID MALE K.A. (i.e. a black carrying red). (Plates I and II.)

The albino female that was used in Cross A was also crossed with a black hybrid male, the son of a pure black father by a pure red mother. The result was 7 black and 2 red offspring in the first brood.

If the constitution of the albino female is $\begin{matrix} c & B \\ c & R \end{matrix}$ and of the hybrid black male $\begin{matrix} C & B \\ C & R \end{matrix}$, the result of the cross should be 3 blacks (one pure and two hybrid) and 1 red, all of them carrying the factor for albino.

Three further broods were obtained from this cross, the total numbers for all four broods being 75 black, 15 red, a proportion 5 : 1 instead of 3 : 1, but three of the broods were not counted until some days after extrusion, which probably accounts for the small proportion of reds.

F.1. GENERATION. BLACKS.

Of the 75 black-eyed young, 49 reached sexual maturity, 27 being males and 22 females. Of these it was possible to test 33 from Broods II, III and IV by mating them together or with mates of known constitution, and 21 proved to be hybrids, i.e. carried both the factors B and R, whilst 12 were pure black. All without exception had albinos amongst their immediate offspring, or transmitted the character to their descendants, showing that both parents possessed the factor c. (Plate I : Broods II, III, IV, V.)

The following list gives the constitution of each individual animal and the different matings made to prove that constitution ; these constitutions are shown in detail on Plates I and II.

II.A. Male, *Black carrying Red and Albino* (Plate II).

Matings :—(1) with female D of the same brood (**B**+A); 88 young, 65 Black, 23 Albino ;

(2) with female VI.A (**B**+R+A) ; 79 young, 49 Black, 15 Red, 15 Albino ;

(3) with a female (**B**+R) (from a mating Pure Black with Pure Red) ; 26 young, 18 Black, 8 Red.

II.C. Male, *Black carrying Red and Albino* (Plate II).

Matings :—(1) with female VI.C. (**B**+R+A) ; 115 young, 74 Black, 15 Red, 26 Albino ;

(2) with Red No-white female from No-white Stock (previously mated with male VI.A.t.) ; 34 young, 18 Black, 16 Red.

II.D. Female, *Black carrying Albino only* (Plate II).

Matings :—(1) with male A of the same brood (89 young, 66 Black, 23 Albino).*

III.A. Male, *Black carrying Red and Albino* (Plate I).

Mating: (1) with female K of the same brood (**B**+R+A); 61 young, 30 Black, 14 Red, 17 Albino.

III.B. Male, *Black carrying Albino only* (proof obtained by mating the offspring).

Matings :—(1) with female L of the same brood (**B**+A); 33 young, 20 Black, 13 Albino.

The first brood of this pair were mated together, and also with Red mates; the resulting young numbered 153, 115 Black and 38 Albino (see Pl. III, Fig. 3, for an example). Black young of the first brood of these were mated together, and gave 19 Black, 3 Albino; mated with Reds they gave 52 young, all Black.

According to these matings both male B and female L are Blacks carrying the Albino factor only.

III.C. Male, *Black carrying Albino only* (probably).

Matings :—(1) with female M of the same brood (**B**+A, Red factor not known); 78 young, 57 Black, 21 Albino.

One of this pair is certainly a (**B**+A), the constitution of the other is not known.

III.D. Male, *Black carrying Albino only.*

Matings :—(1) with female N of the same brood, (**B**+A); 115 young, 78 Black, 37 Albino;

(2) with female VI.B.2.e. (**R**+A); (19 young, 11 Black, 8 Albino);

(3) with female IV.X. (**R**+A); 429 young, 329 Black, 100 Albino.

III.E. Male, *Black carrying Albino.* Red not proved.

Matings :—(1) with female O of the same brood, (**B**+R+A); 5 young, 4 Black, 1 Albino.

III.F. Male, *Black carrying Albino only* (probably).

Matings :—(1) with female P of the same brood; 69 young, 53 Black, 16 Albino.

One of this pair is certainly a (**B**+A), the constitution of the other is not known.

---

* Figures between brackets are also given under the other member of the pair and must therefore not be included in the totals.

III.G. Male, *Black carrying Red and Albino.*

Matings :—(1) with female R of the same brood, (**R**+A) ; 2 young, 1 Black, 1 Red ;

(2) with female O of the same brood, (**B**+R+A) ; 33 young, 22 Black, 2 Red, 9 Albino.

III.H. Male, *Black carrying Red and Albino.*

Matings :—(1) with female Q of the same brood, (**B**+R+A) ; 111 young, 66 Black, 26 Red, 19 Albino.

III.J. Male, *Black carrying Red and Albino.*

Matings :—(1) with female (from wild stock, referred to on p. 329) Black no-white ; 92 young, all Black ;

(2) with female 14.b. (of the same stock as male R.1. on Plate II, see p. 324), Pure Red ; 14 young, 5 Black, 9 Red.

One black-eyed male from mating (1) was mated with an albino female. The first brood of 6 young consisted of 2 black and 4 albino. Hence III.J. must carry albino.

III.K. Female, *Black carrying Red and Albino.*

Matings :—(1) with male A of the same brood, (**B**+R+A) ; (61 young, 30 Black, 14 Red, 17 Albino).

III.L. Female, *Black carrying Albino only.*

Matings :—(1) with male B, (**B**+A) ; (33 young, 20 Black, 13 Albino).

Proof of male B and this female was obtained by mating broods (see under " Male III.B ").

III.M. Female, *Black carrying Albino.* Red not known.

Matings :—(1) with male C of the same brood (see note to that animal) ; (78 young, 57 Black, 21 Albino).

III.N. Female, *Black carrying Albino.*

Matings :—(1) with male D of the same brood, (**B**+A) ; (115 young, 78 Black, 37 Albino) ;

(2) with male VI.A.3 u, (**R**+A) ; (42 young, 32 Black, 10 Albino).

III.O. Female, *Black carrying Albino.*

Matings :—(1) with male E of the same brood, (**B**+A) ; (5 young, 4 Black, 1 Albino) ;

(2) with male G of the same brood, (**B**+R+A) ; (33 young, 22 Black, 2 Red, 9 Albino).

III.P. Female, *Black carrying Albino.* Red factor not proved.

Matings :—(1) with male F of the same brood (**B**+A) ; (69 young, 53 Black, 16 Albino).

III.Q. Female, *Black carrying Red and Albino.*

Matings :—(1) with male H of the same brood, (**B**+R+A) ; (111 young, 66 Black, 26 Red, 19 Albino) ;

(2) with a male from the same brood, (**B**+R+A) ; 19 young, 10 Black, 6 Red, 3 Albino.

The one remaining Black-eyed animal, a male, died without mating.

IV.A. Male, *Black carrying Red and Albino* (Plate I).

Matings :—(1) with female N of the same brood, (**B**+A) ; 6 young, 2 Black, 4 Albino ;

(2) with female T of the same brood, (**B**+R+A) ; 108 young, 64 Black, 21 Red, 23 Albino.

IV.B. Male, *Black carrying Albino.* Red not known.

Matings :—(1) with female O of the same brood, (**B**+A) ; 91 young, 70 Black, 21 Albino.

IV.C. Male, *Black carrying Red and Albino.*

Matings :—(1) with female P of the same brood, (**B**+R+A) ; 61 young, 38 Black, 9 Red, 14 Albino.

IV.D. Male, *Black carrying Red and Albino.*

Matings :—(1) with female Q of the same brood, (**B**+R+A) ; 40 young, 22 Black, 8 Red, 10 Albino.

IV.E. Male, *Black carrying Red and Albino.*

Matings :—(1) with female R of the same brood, (**B**+R+A) ; 49 young, 28 Black, 7 Red, 14 Albino ;

(2) with female Y of the same brood, (**R**+A) ; 19 young, 10 Black, 5 Red, 4 Albino.

IV.F. Male, *Black carrying Albino.* Red not known.

Matings :—(1) with female S of the same brood, (**B**+A); 57 young, 40 Black, 17 Albino.

IV.G. Male, *Black carrying Red and Albino.*

Matings :—(1) with female T of the same brood, (**B**+R+A); 61 young, 33 Black, 15 Red, 13 Albino.

IV.H. Male, *Black carrying Albino only.*

Matings :—(1) with female U of the same brood, (**B**+A, Red not proved); 72 young, 54 Black, 18 Albino.

IV.J. Male, *Black carrying Red and Albino.*

Matings :—(1) with female X of the same brood, (**R**+A); 12 young, 3 Black, 4 Red, 5 Albino;

(2) with female VI.A.3.q. (**B**+R+A); (33 young, 19 Black, 7 Red, 7 Albino).

IV.K. Male, *Black carrying Red and Albino.*

Matings :—(1) with female V of the same brood, (**B**+A); 80 young, 63 Black, 17 Albino;

(2) with female VI.B.1.g. (Pure Red); (9 young, 2 Black, 7 Red).

IV.L. Male, *Black carrying Red (and Albino).*

Matings :—(1) with female Y of the same brood, (**R**+A); 2 young, 1 Black, 1 Red.

IV.M. Male, *Black.* Constitution not known.

IV.N. Female, *Black carrying Albino only.*

Matings :—(1) with a Black male of the same brood; 5 young, all Black.

(8 young were produced from the matings of this brood with Pure Red, 7 Black, 1 Albino.)

(2) with male A of the same brood, (**B**+R+A); (6 young, 2 Black, 4 Albino).

IV.O. Female, *Black carrying Albino only.*

Matings :—(1) with male B of the same brood (**B**+A, Red not known); (91 young, 70 Black, 21 Albino);

(2) with a Black male of the same brood, (**B**+R+A); 32 young, 26 Black, 6 Albino;

(3) with male VI.A.1.m, (Pure Red); (39 young, all Black).

IV.P. Female, *Black carrying Red and Albino.*
Matings :—(1) with male C of the same brood, (**B**+R+A); (61 young, 38 Black, 9 Red, 14 Albino).

IV.Q. Female, *Black carrying Red and Albino.*
Matings :—(1) with male D of the same brood, (**B**+R+A); (40 young, 22 Black, 8 Red, 10 Albino).

IV.R. Female, *Black carrying Red and Albino.*
Matings :—(1) with male E of the same brood, (**B**+R+A); (49 young, 28 Black, 7 Red, 14 Albino).

IV.S. Female, *Black carrying Albino only.*
Matings :—(1) with male F of the same brood, (**B**+A, Red not known); (57 young, 40 Black, 17 Albino);
(2) with a Black male of the same brood, (**B**+R+A); 14 young, 11 Black, 3 Albino;
(3) with male VI.B.1.d (**R**+A); (18 young, 13 Black, 5 Albino).

IV.T. Female, *Black carrying Red and Albino.*
Matings :—(1) with male G of the same brood, (**B**+R+A); (61 young, 33 Black, 15 Red, 13 Albino);
(2) with male A of the same brood, (**B**+R+A); (108 young, 64 Black, 21 Red, 23 Albino).

IV.U. Female, *Black carrying Albino.* Red not proved.
Matings :—(1) with male H of the same brood, (**B**+A); (72 young, 54 Black, 18 Albino).

IV.V. Female, *Black carrying Albino only.*
Matings :—(1) with male K of the same brood, (**B**+R+A); (80 young, 63 Black, 17 Red);
(2) with a Black male of the same brood, either J., K. or M.; 6 young, 3 Black, 3 Albino.
(3) with male VI.A.3.t, (**R**+A); (12 young, 10 Black, 2 Albino).

Brood V. This brood was unhealthy, only a few surviving to mate; the Blacks were not tried for the Red factor.

V.A. Male, *Black carrying Albino*. Red not known.
Matings :—(1) with female D of the same brood, (**B**+A only, probably) ; 17 young, 12 Black, 5 Albino.

V.B. Male, *Black carrying Albino*. Red not known.
Matings :—(1) with female E of the same brood, (**B**+A only, probably) ; 8 young, 6 Black, 2 Albino.

V.C. Male, *Black*. Constitution unknown.

V.D. Female, *Black carrying Albino only* (probably).
Matings :—(1) with a male of the same brood ; 5 young, 4 Black, 1 Albino ;
(2) with male A of the same brood ; (17 young, 12 Black, 5 Albino).

V.E. Female, *Black carrying Albino only* (probably).
Matings :—(1) with a Black male of the same brood ; 3 young, all Albino ;
(2) with male B of the same brood ; (8 young, 6 Black, 2 Albino).

V.F. Female, *Black*. Constitution unknown.
V.G. Female, ...
V.H. Female, ...
V.J.

F.1. Generation. Reds.

Of the 15 Red, 4 males and 6 females reached maturity. (Plate I.) Mated in the same brood they all gave some albino offspring, showing that they contained the factor c.

The following list shows the matings made to prove their constitutions:—

II.B. Male, *Red carrying Albino* (Plate II).
Matings :—(1) with female VI.B ; (**R**+A) ; 101 young, 76 Red, 25 Albino ;
(2) with female 14.a. from the original stock of all-white male R.1. (see p. 324) ;
29 young, all Red (one of these was mated with female VI.C.3.s.) ;
(3) with female 14.b. from same brood as 14.a. ; 30 young, all Red (see p. 324) ;
(4) with female VI.A.2.k. ; (**A**+B+R) ; (146 young, 33 Black, 44 Red, 69 Albino) ;
(5) with female VI.A.1.p. ; (**R**+A) ; 90 young, 66 Red, 24 Albino (Plate IV, Fig. 12).

III.R. Female, *Red carrying Albino* (Plate I).
Matings :—(1) with either male E or male F of the same brood, (**B**+A) ; (6 young, 3 Black, 3 Albino) ;
(2) with male G of the same brood, (**B**+R+A) ; (2 young, 1 Black, 1 Red).

IV.W. Male, *Red carrying Albino* (Plate I).
Matings :—(1) with female Aa, of the same brood, (**R**+A) ; 72 young, 54 Red, 18 Albino ;
(2) with female Z of the same brood, (**R**+A) ; 154 young, 127 Red, 27 Albino ;
(3) with a female (from Brood 1 of III.C.), (**A**+B) ; 56 young, 29 Black, 27 Albino.

IV.X. Female, *Red carrying Albino.*
Matings :—(1) with male J of the same brood, (**B**+R+A) ; (12 young, 3 Black, 4 Red, 5 Albino) ;
(2) with male VI.A.1.e., (**B**+R+A) ; (111 young, 42 Black, 42 Red, 27 Albino) ;
(3) with male III.D, (**B**+A) ; (429 young, 329 Black, 100 Albino).

IV.Y. Female, *Red carrying Albino.*
Matings :—(1) with male L of the same brood, (**B**+R+A) ; (2 young, 1 Black, 1 Red) ;
(2) with male E of the same brood, (B+R+A) ; (19 young, 10 Black, 5 Red, 4 Albino) ;
(3) with a male (Brood 1 of III.B.) ; (A+B) ; (16 young, 12 Black, 4 Albino).

IV.Z. Female, *Red carrying Albino.*
Matings :—(1) with male W of the same brood, (R+A) ; (154 young, 127 Black, 27 Albino) ;
(2) with a male (Brood 1 of III.B.), (**A**+B) ; (65 young, 31 Black, 34 Albino) (Plate III, Fig. 3).

IV. Aa. Female, *Red carrying Albino.*
Matings :—(1) with male W of the same brood, (**R**+A) ; (72 young, 54 Red, 18 Albino).

V.K. Male, *Red.* Constitution not proved.

V.L. Male, *Red carrying Albino,* mated with female M ; 8 young, 6 Red, 2 Albino.

V.M. Female, *Red carrying Albino.*

F.2. Generation. Albinos.

In the F_2 generation the most interesting feature for study is the constitution of the albino offspring. These were mated together successfully in fifteen instances, and without exception gave albino young, the total number of young examined and recorded being 140. (For an example see Plate III, Fig. 1.) One of these young, in addition to having no black or red retinal pigment, also lacked the white accessory pigment and was quite colourless. This specimen is again referred to on p. 339.2. In addition to these separate matings, the albino young of III were put together in a jar to breed, producing 15 young, all Albino. Two others were mated with albinos from VI, and had 138 young, all Albino.

The albinos may carry either (1) pure black, (2) pure red or (3) both black and red. Amongst the F_2 offspring belonging to this section the constitution has been proved in the following cases :—

(1) *Albino carrying pure black.*

One male (II.D.1.k.) mated with a red no-white gave 38 young, all black-eyed.

One male (Brood 1 of III.B.) mated with a red female from the same stock (carrying albino) gave 12 black and 4 albino.

One male (Brood 1 of III.B.) mated in the same way gave 31 black and 34 albino (Plate III, Fig. 3).

One female (Brood 1 of III.C.) mated with a red male (IV.W.) from the same stock (carrying albino) gave 29 black and 27 albino.

(2) *Albino carrying red.*

One female (from a brood of female I.G.) mated with a pure red male of the same brood gave 12 all red young (Plate III, Fig. 4).

Another similar female (from the same brood as above) mated with a male of the same brood (red carrying the factor for albino) gave 7 red and 10 albino young (Plate III, Fig. 5).

(3) *Albino carrying black and red.*

One male (II.D.1.j.) mated with a red no-white gave 42 black and 38 red young (Plate III, Fig. 6).

The original albino female AC was like this.

SECTION II. THE ALL-WHITE PERFECT EYE.

In the former paper (p. 45 and Fig. 8) a second form of white eye, i.e. one of perfect form but with no black or red retinal pigment, and with only the extra-retinal chalk-like white accessory pigment, was described and figured. This occurred in the pure red stock and the details of the origin of the only two indviduals of the kind that were seen are given in the paper referred to. Only one individual, a male, survived to produce offspring. The stock has not since produced any more of them.

Cross C.

CROSS BETWEEN ALBINO IMPERFECT-EYED FEMALE AB. AND "ALL-WHITE" PERFECT-EYED MALE R.1. (Plate VII, Figs. 4 and 7; Plate II.)

The male just referred to was mated with an albino imperfect-eyed female (AB) from the degenerate-eyed stock described on p. 275. There resulted 2 black and 3 red-eyed offspring all normal eyed as regards form, and the male died in moulting without mating again (Plate II). The fact that two parents, neither of which showed any coloured pigment, produced all coloured-eyed offspring seemed to make this case specially interesting and some pains have been taken to investigate it thoroughly. Since the male came from pure red stock, and some black-eyed offspring were obtained it seems clear that the black came from the female which must, since both black and red offspring were produced, have contained the red factor also. This female was therefore an albino carrying both black and red, like the sister from the same brood whose offspring we have already studied in **Cross A**.

There seem to be two possible ways of regarding this case, in which two albino parents produced coloured offspring. Following Bateson and Punnett we may endeavour to explain it by supposing that the factor for red has been lost in the perfect-eyed male, whilst a "colour factor," which must be present if colour is to appear, has been retained in the male, but is absent in the female. If we represent the colour factor by C and its absence by c, the constitution of the male would be $\frac{C}{C}$, that of the female $\frac{c\,B}{c\,R}$. On the other hand, it may be that the absence of colour in the male is a somatic and not a germinal character, and is not inherited at all. Breeding experiments carried on to the fourth generation have shown that this second supposition is the true one, and that the "all-white" male from the pure red stock behaves, as regards its offspring, exactly as if it were a pure red.

Of the offspring of the cross between the "all-white" perfect-eyed male and the albino imperfect-eyed female, three only survived until they were mature, 2 black-eyed and 1 red-eyed, all being females. Of the F_1 offspring of the cross between the imperfect albino and the hybrid black already dealt with (**Cross B**) there were four survivors of the first brood (II), one black female, one red and two black males, as already described. At this stage of the investigation it was important to increase as quickly and with as little risk as possible the stock of albino-eyed animals. This could be most easily done by crossing the two broods, which soon gave us large numbers of albino-eyed offspring. This crossing of the two broods has somewhat complicated the analysis necessary for the determination of the germinal constitution of the perfect-eyed "all-white" male, but the result nevertheless appears to be definite and not without interest.

The following matings were made, the offspring of **Cross C** being designated VI, those of **Cross B** being II (Plate II) :—

(1) VI.A. (Black female) × II.A. (Black male). The offspring were black, red and albino, hence both male and female were hybrids, carrying factors for black, red and albino.

(2) VI.C. (Black female) × II.C. (Black male). Again the offspring were black, red and albino, and both male and female therefore hybrids.

(3) VI.B. (Red female) × II.B. (Red male). Offspring red and albino.

(1) and (2) being quite similar crosses their offspring may be added together. In three broods from each, examined immediately the young were extruded, there were 91 black, 26 red and 37 albino, a total of 154 young.

In the cross of the two reds (3), out of 101 young there were 76 red and 25 albino.

We must now proceed to consider the analysis of these matings according to the two hypotheses for the constitution of the perfect-eyed "all-white" male already mentioned, in order to determine which, if either, of the two hypotheses is correct.

Taking first the cross between the two blacks, we have :—

Hypothesis I. On the first hypothesis the constitution of the all-white perfect-eyed male will be $\frac{C}{C}$, that of the albino female carrying black and red $\frac{c\ B}{c\ R}$. The gametes for the male will therefore be C only, for the female c B and c R. The F_1 zygotes resulting from the mating of these two will be C c B and C c R, giving black and red-eyed animals in equal numbers.

The constitution of the albino imperfect-eyed female is $\begin{matrix} c\ B \\ c\ R \end{matrix}$ as already seen on p. 276, that of the hybrid black male with which it was mated is $\begin{matrix} C\ B \\ C\ R \end{matrix}$. The gametes are therefore for the male C B and C R, for the female c B and c R. The F_1 zygotes resulting from the mating of these two will be one C c B B, a black carrying albino, two C c B R, blacks carrying red and albino, and one C c R R, a red carrying albino.

If we now cross an F_1 black from the first of the above matings with an F_1 hybrid black from the second, we have :—

VI.A. ♀× ♂ II.A.
CcB× CcBR

Female gametes :—	C B,	C,	c B,	c
Male ,,	C B,	C R,	c B,	c R
F_2 Zygotes	C B C B	C C B	c B C B	c C B
	C B C R	C C R	c B C R	c C R
	C B c B	C c B	c B c B	c c B
	C B c R	c c R	c B c R	c c R

That is 9 black, 3 red and 4 albino.

HYPOTHESIS II. On the second hypothesis the all-white perfect-eyed male is constitutionally a pure red, but the non-appearance of the red is a pathological condition which is not inheritable. Its constitution may then be represented as $\begin{matrix} C\ R \\ C\ R \end{matrix}$, and if it is mated with the albino female carrying black and red we shall have :—

$$\begin{matrix} C\ R & c\ B \\ C\ R & c\ R \end{matrix}$$

The gametes for the male will therefore be C R only, for the female c B and c R.

The F_1 zygotes resulting from the mating of these two will be C c B R and C c R R, giving black and red-eyed animals in equal numbers.

If one of these F_1 black-eyed animals (VI) is mated with a black from brood II, carrying red, we shall have :—

VI.A. ♀× ♂ II.A.
C c B R× C c B R

Female Gametes C B, C R, c B, c R
Male ,, the same as the female.
F_2Zygotes

C B C B	C B C R	C B c B	C B c R
C R C B	C R C R	C R c B	C R c R
c B C B	c B C R	c B c B	c B c R
c R C B	c R C R	c R c B	c R c R

That is 9 Black, 3 red and 4 albinos.

It will be seen therefore that according to either theory the visible result should be exactly the same in the F_2 generation, viz. :—

9 *Black*, 3 *Red*, 4 *Albino*. The experimental result was
91 black, 26 red, 37 albino and theory requires
87 ,, 29 ,, 38 ,, which is a good agreement.

The germinal constitution will however be different according to which hypothesis is true. We will consider the different colour classes separately.

Under *Hypothesis I* there would be six different kinds of black-eyed animals, which in every sixteen animals would occur on the average as follows :—

one normal pure black, without the albino factor ; (C C B B) ;
two ,, ,, ,, with ,, ,, ,, (C c B B) ;
one pure black, with one dose of black only instead of two, and without the albino factor ; (C C B) ;
two ,, ,, with one dose of black and with the albino factor ; (C c B) ;
one black carrying red, without the albino factor ; (C C B R) ;
two ,, ,, ,, with ,, ,, ,, (C c B R).

Under *Hypothesis II* there would be only four different kinds of black-eyed animals, viz. :—

one normal pure black, without the albino factor ; (C C B B) ;
two ,, ,, ,, with ,, ,, ,, (C c B B) ;
two black carrying red, without ,, ,, ,, (C C B R) ;
four ,, ,, ,, with ,, ,, ,, (C c B R).

The difference between the results given by the two hypotheses is that under II there are no blacks with one dose of black only, their place being taken by additional hybrid blacks.

One means of testing the hypotheses, therefore, will be to find out by further breeding experiments whether or not the F_2 offspring contain blacks with one dose of black. If a one-dose black be mated with another one-dose black the offspring will be all black, if mated with a two-dose black they will be all black, but if mated with a hybrid black (black carrying red) the offspring will contain some red, as we have seen in considering the cross VI.A. × II.A.

If we mate together the blacks of the F_2 generation we obtain in F_3 some broods which contain red-eyed animals, others which contain only blacks. The parents of the broods containing red eyes will either be two hybrids, or a hybrid and a one-dose black, if the latter exists. If we cross-mate the parents of a number of such broods, in as many different ways as possible, we ought eventually to bring two one-dose blacks together, in which case we should get all black offspring.

A second test will be as follows. If a one-dose black be mated with a red it will, according to theory, give blacks and reds in equal numbers, behaving in exactly the same way as a hybrid black. If therefore we take blacks which give red offspring when mated with red, and mate them together, we ought, if the one-dose black exists, to obtain some broods which give all black as the result of two one-dose blacks coming together.

By mating together blacks tested with reds in this way, and blacks tested with other blacks and giving red in their broods, we have a further opportunity of bringing together two one-dose blacks (if they exist).

These tests have been applied, but we have not been able to find any one-dose blacks, all those tried proving ordinary hybrid blacks, giving both red and black offspring. (See list of cross-matings, p. 303.)

Cross C. F.2. Generation. Blacks.

The following lists show (1) the constitutions of all the blacks of these broods which have been tested (see Plate II, VI.A and VI.C); and (2) the results of the cross-matings made with blacks which had given some red offspring when mated with either red or black mates :—

(1) The Black-eyed young, showing their constitution and the matings by which they were proved.

VI.A.1.a. Male, *Black carrying the factor for Red only* (Plate IV, Figs. 2, 4 and 5).

Matings :—(1) with female from Pure Red Stock ; 8 young, 5 Black, 3 Red ;

(2) with female 1 of its own brood, (**B**+R+A) ; 61 young, 49 Black, 12 Red ;

(3) with female of VI.C.1.d. (**B**+R+A) ; 42 young, 30 Black, 12 Red.

VI.A.1.b. Male, *Black carrying Red only.*

Matings :—(1) with female from Pure Red Stock ; 15 young, 5 Black, 10 Red ;

(2) with female g of its own brood (**B**+R+A) ; 27 young, 23 Black, 4 Red ;

(3) with female f of its own brood, (**B**+R+A) ; 25 young, 17 Black, 8 Red.

VI.A.1.c. Male, *Pure Black* (Plate IV, Figs. 7 and 8).

Matings :—(1) with female from Pure Red Stock, 16 young, all Black ;

(2) with female q of its own brood, (**R**+A) ; 45 young, all Black.

VI.A.1.d. Male, *Black carrying Red and Albino.*

Matings :—(1) with female from Pure Red Stock ; 10 young, 3 Black, 7 Red.

(2) (3) (4) (5) with four other females, which it ate ;

(6) with female VI.B.2.u. (**A**+R) ; 24 young, 1 Black, 3 Red, 20 Albino * ;

(7) with female VI.A.3.q. (**B**+R+A) ; 16 young, 10 Black, 2 Red, 4 Albino.

VI.A.1.e. Male, *Black carrying Red and Albino.*

Matings :—(1) with female from Pure Red Stock ; 18 young, 11 Black, 7 Red ;

(2) with female VI.C.1.h. (**B**+R) ; 88 young, 60 Black, 28 Red ;

(3) with female IV.X. (**R**+A) ; 111 young, 42 Black, 42 Red, 27 Albino.

VI.A.1.f. Female, *Black carrying Red and Albino.*

Matings :—(1) with male from Pure Red Stock ; 12 young, 4 Black, 8 Red ;

(2) with male VI.C.1.m. (**R**+A) ; 71 young, 31 Black, 18 Red, 22 Albino ;

(3) with male b of its own brood ; (25 young, 17 Black, 8 Red) ;

(4) with male VI.A.3.c. (**B**+R+A) ; 5 young, 2 Black, 1 Red, 2 Albino.

---

* Compare footnote p. 344. The exceptional numbers were specially noted at the time the brood was extruded, and there is no doubt as to the accuracy of the record.

VI.A.1.g. Female, *Black carrying Red and Albino.*

Matings :—(1) with male from Pure Red Stock ; 10 young, 5 Black, 5 Red ;
(2) with male b, of its own brood ; (27 young, 23 Black, 4 Red) ;
(3) with male VI.C.1.m. (**R**+A) ; 22 young, 10 Black, 8 Red, 4 Albino.

VI.A.1.h. Female, *Black carrying Red and Albino.*

Matings :—(1) with male from Pure Red Stock ; 7 young, 3 Black, 4 Red ;
(2) with male o of its own brood, Pure Red ; 31 young, 17 Black, 14 Red.

That the female carried the factor for Albino was proved by mating the young of the first brood, when Black, Red, and Albino eyes appeared in the offspring (207 young, 89 Black, 106 Red, 12 Albino). One Red male was also mated with female VI.C.3.e. and one Red male with female VI.B.1.f. and a Black female with male VI.B.2.t.

VI.A.1.j. Female, *Black carrying Red, albinism not known.*

Mating :—(1) with male from Pure Red Stock ; 19 young, 7 Black, 12 Red ;

VI.A.1.k. Female, *Black carrying Red only.*

Mating :—(1) with male from Pure Red Stock ; 17 young, 8 Black, 9 Red.

Of the young of this brood 11 survived to maturity ; from their matings in the bowl 77 young have been obtained, 38 Black, 39 Red, but no albino-eyed young have appeared.

VI.A.1.l. Female, *Black carrying Red and Albino* (Plate IV, Figs. 1, 2 and 3).

Matings :—(1) with male from Pure Red Stock ; 73 young, 39 Black, 34 Red ;
(2) with male a of its own brood ; (61 young, 49 Black, 12 Red) ;
(3) with male VI.C.1.o. (**R**+A) ; 82 young, 37 Black, 24 Red, 21 Albino (and 21 others not examined).

Three other black-eyed young were hatched, two died, immature, and the third, a female, which reached maturity was eaten by its mate.

VI.A.2.a. Male, *Black carrying Red and Albino.*

Matings :—(1) with female k of its own brood, (**A**+B+R); 7 young, 2 Black, 1 Red, 4 Albino ;

(2) with female VI.B.3.e. (Pure Red) ; 20 young, 8 Black, 12 Red.

VI.A.2.b. Male, *Black, factors carried not known.*

Mating:—(1) with Red female VI.B.3.g. ; 5 young, all Black.

Both male and female died before mating again ; constitution therefore of both unknown.

VI.A.2.c. Female, *Black carrying Red only.*

Matings :—(1) with male VI.A.3.h. (**B**+A) ; 46 young, all Black ;

(2) with male VI.B.2.d. (**R**+A) ; 27 young, 16 Black, 11 Red ;

(3) with male VI.A.3.d. (**B**+R) ; 43 young, 29 Black, 14 Red.

VI.A.2.d. Female, *Black carrying Albino.*

Mating :—(1) with male VI.A.3.aa. (**A**+R) ; 18 young, 8 Black, 10 Albino.

VI.A.2.e. Female, *Black carrying Albino.*

Mating :—(1) with male VI.A.3.aa. (**A**+R) ; 29 young ; 13 Black, 16 Albino.

VI.A.2.f. Female, *Black carrying Albino.*

Mating :—(1) with male VI.A.3.aa. (**A**+R) ; 30 young, 12 Black, 18 Albino.

11 others ; 9 died immature ; one male and one female which reached maturity, died without mating.

VI.A.3.a. Male, *Black, Red not known. No Albino.*

Matings :—(1) with female k of the same brood (**B**+A) ; 18 young, all Black.

(Chance matings amongst these 18 black young gave 29 young, all black.)

(2) with female VI.A.1.l. Eggs laid, but female died before they were hatched.

VI.A.3.b. Male, *Black carrying Albino.*

Matings :—(1) with female l of the same brood (**B**+A, R not proved) ; 4 young, all Black ;

(2) with female bb. of the same brood (**A**+B+R) ; 14 young, 2 Black, 12 Albino ;

(3) with female I.D.2.d. (**A**+B+R)*; 7 young, 3 Black, 4 Albino.

---

* This constitution was proved after Plate I was printed.

VI.A.3.c. Male, *Black carrying Red and Albino.*

Matings :—(1) with female m of the same brood, (**B**+R+A) ; 28 young, 18 Black, 6 Red, 4 Albino ;
(2) with female VI.A.1.f. (**B**+R+A) ; (5 young, 2 Black, 1 Red, 2 Albino) ;
(3) with female VI.C.1.d., (**B**+R+A) ; 71 young, 36 Black, 15 Red, 20 Albino ;
(4) with female VI.C.3.d. (**B**+R) ; 11 young, 9 Black, 2 Red.

VI.A.3.d. Male, *Black carrying Red only.*

Matings :—(1) with female n of the same brood (**B**+R+A) ; 46 young, 41 Black, 5 Red ;
(2) with female VI.C.1.d. (**B**+R+A) ; 115 young, 91 Black, 24 Red ;
(3) with female VI.A.2.c. (**B**+R) ; (43 young, 29 Black, 14 Red) ;
(4) with female VI.C.3.e. (**B**+R+A) ; 56 young, 46 Black, 10 Red.

VI.A.3.e. Male, *Pure Black.*

Matings :—(1) with female o of same brood, (**B**+A, R not proved) ; 9 young, all Black ;
(2), (3), (4), (5) with 4 other females, which it ate ;
(6) with female VI.B.2.v. (**A**+R) ; 19 young, all Black.

VI.A.3.f. Male, *Black carrying Red and Albino.*

Matings :—(1) with female p of its own brood, (**B**+R+A) ; 13 young, 6 Black, 2 Red, 5 Albino.

VI.A.3.g. Male, *Black carrying Albino.*

Matings :—(1) with female q of its own brood, (**B**+R+A) ; 55 young, 35 Black, 20 Albino ;
(2) with female III Q. (**B**+R+A) ; 37 young, 27 Black, 10 Albino.

VI.A.3.h. Male, *Black carrying Albino.*

Matings :—(1) with female VI.A.2.c. (**B**+R) ; (46 young, all Black) ;
(2) with female VI.B.2.v. (**A**+R) ; 92 young, 52 Black, 40 Albino.

VI.A.3.j. Male, *Black.* Constitution not known.

Matings :—(1) with female s of the same brood ; 1 young Black.

VI.A.3.k. Female, *Black carrying Albino.*

Matings :—(1) with a Black male of the same brood; 6 young, 5 Black, 1 Albino;
(2) with male a of the same brood; (18 young, all Black);
(3) with male VI.C.1.p. (**R**+A); 38 young, 27 Black, 11 Albino.

VI.A.3.l. Female, *Black carrying Albino.* Red not proved.

Matings :—(1) with a Black male of the same brood; 5 young, all Black;
(2) with male b of the same brood, (**B**+A); (4 young, all Black).

Only one young survived to maturity, and was mated with a Red female carrying albino; 19 offspring were produced, 8 Black and 11 Albino.

VI.A.3.m. Female, *Black carrying Red and Albino.*

Matings :—(1) with a Black male of the same brood, 1 young, Black;
(2) with male c of the same brood, (**B**+R+A); (28 young, 18 Black, 6 Red, 4 Albino).

VI.A.3.n. Female, *Black carrying Red and Albino.*

Matings :—(1) with male d of the same brood, (**B**+R); (46 young, 41 Black, 5 Red).

From the matings of these, 73 young were produced, 69 Black, 2 Red and 2 Albino.

VI.A.3.o. Female, *Black carrying Albino.* Red factor not proved.

Matings :—(1) with a Black male of the same brood; 5 young, 4 Black, 1 Albino;
(2) with male e of the same brood, (Pure Black); (9 young, all Black).

As these young all died before reaching maturity, it was not possible to test the brood for Reds.

VI.A.3.p. Female, *Black carrying Red and Albino.*

Matings :—(1) with a black male of the same brood; 6 young, 3 Black, 3 Albino;
(2) with male f of the same brood, (**B**+R+A); (13 young, 6 Black, 2 Red, 5 Albino).

VI.A.3.q. Female, *Black carrying Red and Albino.*

Matings :—(1) with male g of the same brood, (**B**+A) ; (55 young, 35 Black, 20 Albino) ;

(2) with male IV.J. (**B**+R+A) ; 33 young, 19 Black, 7 Red, 7 Albino ;

(3) with male VI.A.1.d. (**B**+R+A) ; (16 young, 10 Black, 2 Red, 4 Albino).

VI.A.3.r. Female, *Black carrying Red and Albino.*

Matings :—(1) with a Black male of the same brood ; 7 young, 4 Black, 3 Albino ;

(2) with male VI.C.3.a. (**B**+R+A) ; 8 young, 3 Black, 2 Red, 3 Albino.

VI.A.3.s. Female, *Black.* Constitution not proved.

Matings :—(1) with a Black male of the same brood ; 4 young, all Black ;

(2) with male j of the same brood ; (1 young, Black).

VI.C.1.a. Male, *Black carrying Albino.*

Matings :—(1) with a female from Pure Red Stock ; 66 young, all Black ;

(2) with an Albino female I.D.2.d. ; 49 young, 24 Black, 25 Albino.

VI.C.1.b. Male, *Black carrying Red and Albino.*

Matings :—(1) with female f of the same brood (**B**+R+A) ; 74 young, 41 Black, 15 Red, 18 Albino (Plate IV, Fig. 15) ;

(2) with female k of the same brood (**B**+A) ; 27 young, 20 Black, 7 Albino (Plate IV, Fig. 14).

VI.C.1.c. Male, *Black carrying Red and Albino.*

Matings :—(1) with a female from Pure Red Stock ; 53 young, 33 Black, 20 Red ;

(2) with female l of the same brood (**B**+R+A) ; 17 young, 12 Black, 3 Red, 2 Albino.

VI.C.1.d. Female, *Black carrying Red and Albino.*

Matings :—(1) with male n of the same brood (**R**+A) ; 96 young, 37 Black, 35 Red, 24 Albino ;

(2) with male o of the same brood, (**R**+A) ; 39 young, 12 Black, 16 Red, 11 Albino (Plate IV, Fig. 6) ;

Matings: (3) with male VI.A.1.a. (**B**+R); (42 young, 30 Black, 12 Red) (Plate IV, Fig. 5):
(4) with male VI.A.3.d. (**B**+R); (80 young, 62 Black, 18 Red);
(5) with male VI.A.3.c. (**B**+R+A); (71 young, 36 Black, 15 Red, 20 Albino).

VI.C.1.e. Female, *Pure Black.*
Matings:—(1) with male o of the same brood (**R**+A); 42 young, all Black;
(2) with male n of the same brood, (**R**+A); 49 young, all Black.

VI.C.1.f. Female, *Black carrying Red and Albino.*
Matings:—(1) with male b of the same brood (**B**+R+A); (74 young, 41 Black, 15 Red, 18 Albino) (Plate IV, Fig. 15);
(2) with male p of the same brood (**R**+A); 78 young, 32 Black, 23 Red, 23 Albino (and 11 others not examined).

VI.C.1.g. Female, *Black carrying Red and Albino.*
Matings:—(1) with a male of the same brood (either b or c), (**B**+R+A); 17 young, 8 Black, 5 Red, 4 Albino.

VI.C.1.h. Female, *Black carrying Red only.*
Matings:—(1) with male p of the same brood (**R**+A); 40 young, 16 Black, 24 Red;
(2) with male VI.A.1.e. (**B**+R+A); (88 young, 60 Black, 28 Red);
(3) with male VI.C.3.b. (**B**+R+A); 12 young, 8 Black, 4 Red.

VI.C.1.j. Female, *Black carrying Red only.*
Matings:—(1) with a male from Pure Red Stock; 58 young, 25 Black, 33 Red.

These broods were mated together on reaching maturity; 64 young were produced, Black and Red, no Albinos.

VI.C.1.k. Female, *Black carrying Albino only.*
Matings:—(1) with a male from Pure Red Stock; 82 young, all Black (Plate IV, Fig. 13);
(2) with male b of the same brood (**B**+R+A); (27 young, 20 Black, 7 Albino) (Plate IV, Fig. 14).

VI.C.1.l. Female, *Black carrying Red and Albino.*

Matings :—(1) with a male from Pure Red Stock ; 40 young, 18 Black, 22 Red ;
(2) with male c of the same brood (**B**+R+A) ; (17 young, 12 Black, 3 Red, 2 Albino).

VI.C.2.a. Male, *Black carrying Red and Albino.*

Matings :—(1) with female f of the same brood (**B**+R+A) ; 18 young, 7 Black, 2 Red, 7 Albino, (and 2 others eaten).

VI.C.2.b. Male, *Black carrying Red and Albino.*

Matings :—(1) with female g of the same brood (**B**+R+A) ; 21 young, 10 Black, 4 Red, 7 Albino.

VI.C.2.c. Male, *Black carrying Albino only.*

Matings :—(1) with female h of the same brood, Black carrying Albino only probably ; 8 young, 6 Black, 2 Albino ;
(2) with female VI.B.3.f. (**R**+A) ; 6 young, 5 Black, 1 Albino.

VI.C.2.d. Male, *Pure Black.*

Matings :—(1) with female j of the same brood ; 67 young, all Black ;
(2) with female VI.B.2.g. (Pure Red) ; 23 young, all Black ;
(3) with female VI.B.2.v. (**A**+R) ; 21 young, all Black.

VI.C.2.e. Male, *Black carrying Red and Albino.*

Matings :—(1) with female k of the same brood (**B**+R+A) ; 8 young, 7 Black, 1 Albino ;
(2) with female l of the same brood (**B**+R+A) ; 27 young, 15 Black, 3 Red, 9 Albino.

VI.C.2.f. Female, *Black carrying Red and Albino.*

Matings :—(1) with either male b or male e of the same brood (**B**+R+A) ; 12 young, 4 Black, 1 Red, 7 Albino ;
(2) with male a of the same brood (**B**+R+A) ; (18 young, 7 Black, 2 Reds, 7 Albino and 2 others eaten).

VI.C.2.g. Female, *Black carrying Red and Albino.*

Matings :—(1) with a male of the same brood (probably male d Pure Black); 6 young, all Black ;
(2) with male b of the same brood (**B**+R+A) ; (21 young, 10 Black, 4 Red, 7 Albino).

VI.C.2.h. Female, *Black carrying Albino only* (probably).

Matings :—(1) with a male of the same brood (probably male d, Pure Black) ; 8 young, all Black ;
(2) with male c of the same brood (**B**+A) ; (8 young, 6 Black, 2 Albino).

Only three of this brood came to maturity, 1 male and 2 Black females. The male mated with one female and had 4 young, 2 Black and 2 Albino. The females were mated with Red males, and gave (1) 2 Black and (2) 25 Black and 4 Albino ; no Reds.

VI.C.2.j. Female, probably *Pure Black* (other factors not proved).

Matings :—(1) with a Black male of the same brood ; 7 young, all Black ;
(2) with male d of the same brood, (Pure Black) ; (67 young, all Black).

Of these young, only two males survived to maturity ; mated with Albino females (**A**+R) they gave 10 young, all Black.

VI.C.2.k. Female, *Black carrying Red and Albino.*

Matings :—(1) with male b or e of the same brood (**B**+R+A) ; 13 young, 7 Black, 2 Red, 4 Albino ;
(2) with male e of the same brood ; (**B**+R+A); (8 young, 7 Black, 1 Albino) ;
(3) with male u of the same brood (**A**+R) ; 21 young, 17 Black, 1 Red, 3 Albino.

VI.C.2.l. Female, *Black carrying Red and Albino.*

Matings :—(1) with a Black male of the same brood ; 4 young, 2 Black, 2 Albino ;
(2) with male e of the same brood, (**B**+R+A) ; (27 young, 15 Black, 3 Red, 9 Albino).

The remaining one, a male, died before its constitution was proved.

VI.C.3.a. Male, *Black carrying Red and Albino.*

Matings :—(1) with female VI.A.3.r. (**B**+R+A) ; (8 young, 3 Black, 2 Red, 3 Albino).

VI.C.3.b. Male, *Black carrying Red and Albino.*

Matings :—(1) with female VI.B.2.e. (**R**+A) ; 38 young, 15 Black, 12 Red, 11 Albino ;
(2) with female VI.C.1.h. (**B**+R) ; (12 young, 8 Black, 4 Red) ;
(3) with female g of the same brood, (**B**+R) ; 18 young, 13 Black, 5 Red.

VI.C.3.c. Male, *Black carrying Albino only.*

Matings :—(1) with female VI.A.3.w. (**R**+A) ; (17 young, 15 Black, 2 Albino).

VI.C.3.d. Female, *Black carrying Red only.*

Matings :—(1) with male n of the same brood (Red, albinism not known) ; 16 young, 13 Black, 3 Red ;
(2) with male VI.A.3.t. (**R**+A) ; (25 young, 12 Black, 13 Red) ;
(3) with male VI.A.3.c. (**B**+R+A) ; (11 young, 9 Black, 2 Red).

VI.C.3.e. Female, *Black carrying Red and Albino.*

Matings :—(1) with a male, Pure Red (from the same stock as R.1 on Plate II, see page 324) ; 7 young, 5 Black, 2 Red ;
(2) with male VI.B.2.t. (**A**+R) ; 28 young, 13 Black, 4 Red, 11 Albino ;
(3) with a male from Brood 1 of female VI.A.1.h. (Pure Red) ; 34 young, 22 Black, 12 Red ;
(4) with male VI.A.3.d. (**B**+R) ; (56 young, 46 Black, 10 Red).

VI.C.3.f. Female, *Black carrying Albino only.*

Matings :—(1) with male VI.B.3.b. (**R**+A) ; 25 young, 21 Black, 4 Albino.

VI.C.3.g. Female, *Black carrying Red only.*

Matings :—(1) with male VI.C.2.u. (**A**+R) ; (28 young, 13 Black, 15 Red) ;
(2) with male b of the same brood (**B**+R+A) ; (18 young, 13 Black, 5 Red).

VI.C.3.h. Female, *Pure Black.*

Matings :—(1) with male VI.A.2.g. (**A**+R) ; (29 young, all Black).

VI.C.3.j. Female, *Black carrying Albino only.*

Matings :—(1) with male p of the same brood (**A**+R) ; 31 young, 14 Black, 17 Albino ;

(2) with a male (from Brood 1 of male VI.C.2.p.) (**A**+R) ; 9 young, 4 Black, 5 Albino.

VI.C.3.k. Female, *Black carrying Albino.* Red not known.

Matings :—(1) with a Black male of the same brood ; 6 young, 3 Black, 3 Albino.

This brood died before reaching maturity, and could not therefore be tested for Reds.

(2) with male VI.A.2.j. Died.

VI.C.3.l. Female, *Black.* Constitution not proved.

Matings :—(1) with Red male I.E.1.a. ; 2 young, Black.

These died without mating.

To sum up, 69 animals were tested, 28 males and 41 females ; 58 of these gave conclusive results, while six others are marked "doubtful," either because the number of offspring obtained was not considered quite sufficient, or because the animal after being proved for one factor, red or albino, died before the presence or absence of the second factor could be definitely established. The remaining five gave no definite results.

The proportions should be, according to Hypothesis II, 1 : 2 : 2 : 4, which for 64 would be 7 : 14 : 14 : 28.

The actual figures counting the "doubtfuls" are 7 : 17 : 10 : 30. They were divided as follows :-

Pure Blacks, 5, three males and two females, 2 others, male and female, "doubtful," i.e. showing neither the red nor the albino factor in their young nor in the matings obtained from these.

Black carrying Albino only, 14, six males and eight females, 3 others, females, "doubtful," i.e. no proof of the red factor.

Black carrying Red only, 9, three males and six females, 1 other, female, "doubtful," i.e. no proof of the albino factor.

Black carrying Red and Albino, 30, thirteen males and seventeen females.

In all, 3,137 young were obtained from these matings, 32 of which were not examined for eye-colour.

The matings *Black* by **R** ; by **R**+A ; by **A**+R, 222 young all Black.

Black by **B** ; by **B**+A ; by **B**+R+A, 121 all Black.

Black carrying Albino, by **R** ; 148 all Black : by **R**+A ; 53 Black and 16 Albino : by **A**+R, 103 Black, 106 Albino.

Black carrying Albino, by **B**+R+A, 92 Black, 45 Albino : by **A**+B+R, 29 Black, 41 Albino : by **B**+A, 15 Black, 8 Albino : by **B**+R, 51 all Black.

Black carrying Red, by **R**, and **R**+A, 95 Black, 105 Red.

Black carrying Red, by **B**+R, 29 Black, 14 Red : by **B**+R+A, 387 Black, 114 Red.

Black carrying Red and Albino, by **R**, 168 Black, 147 Red : by **R**+A, 216 Black, 178 Red, 143 Albino : by **A**+R, 31 Black, 8 Red, 34 Albino.

Black carrying Red and Albino, by **B**+R+A, 205 Black, 72 Red, 104 Albino : by **A**+B+R, 2 Black, 1 Red, 4 Albino.

[In the F_3 generation proceeded with for proof 450 young (F_4) were produced, 272 Black, 147 Red and 31 Albino.]

(2) **List of the cross-matings** made with the black-eyed animals which had given some red offspring when mated with reds or other blacks :

VI.A.1.a. Male (**B**+R) : tested with Red : 5 Black, 3 Red.
(1) crossed with female VI.A.1.l. (**B**+R+A) ; 45 Black, 11 Red ;
(2) crossed with female VI.C.1.d. (**B**+R+A) : 30 Black, 12 Red.

VI.A.1.b. Male (**B**+R) : tested with Red : 5 Black, 10 Red.
(1) crossed with female VI.A.1.g. (**B**+R+A) ; 23 Black, 4 Red ;
(2) crossed with female VI.A.1.f. (**B**+R+A) ; 17 Black, 8 Red.

VI.A.1.d. Male (**B**+R+A) : tested with Red : 3 Black, 7 Red.
(1) crossed with female VI.A.3.q. (**B**+R+A) ; 10 Black, 2 Red, 4 Albino.

VI.A.1.e. Male (**B**+R+A) : tested with Red : 11 Black, 7 Red.
(1) crossed with female VI.C.1.h. (**B**+R) ; 60 Black, 28 Red.

VI.A.1.f. Female (**B**+R+A) : tested with Red : 4 Black, 8 Red.
(1) crossed with male b, see above ;
(2) crossed with male VI.A.3.c. (**B**+R+A) ; 2 Black, 1 Red, 2 Albino.

VI.A.1.g. Female (**B**+R+A); tested with Red: 5 Black, 5 Red.
(1) crossed with male b (**B**+R), see above.

VI.A.1.l. Female (**B**+R+A): tested with Red: 39 Black, 34 Red.
(1) crossed with male a (**B**+R), see above.

VI.A.2.c. Female (**B**+R): tested with Red carrying Albino: 16 Black, 11 Red.
(1) crossed with male VI.A.3.d. (**B**+R); 29 Black, 14 Red.

VI.A.3.c. Male (**B**+R+A).
(1) crossed with female VI.A.3.m. (**B**+R+A); 18 Black, 6 Red, 4 Albino;
(2) crossed with female VI.A.1.f. (**B**+R+A); see above;
(3) crossed with female VI.C.1.d. (**B**+R+A); 36 Black, 15 Red, 20 Albino;
(4) crossed with female VI.C.3.d. (**B**+R); 9 Black, 2 Red.

VI.A.3.d. Male (**B**+R).
(1) crossed with female VI.A.3.n. (**B**+R+A); 41 Black, 5 Red;
(2) crossed with female VI.C.1.d. (**B**+R+A); 91 Black, 24 Red;
(3) crossed with female VI.A.2.c. (**B**+R); see above;
(4) crossed with female VI.C.3.e. (**B**+R+A); 46 Black, 10 Red.

*VI.A.3.f. Male (**B**+R+A).
(1) crossed with female VI.A.3.p. (**B**+R+A); 6 Black, 2 Red, 5 Albino.

*VI.A.3.m. Female (**B**+R+A).
(1) crossed with male VI.A.3.c. (**B**+R+A); see above.

*VI.A.3.p. Female (**B**+R+A).
(1) crossed with male VI.A.3.f. (**B**+R+A); see above.

*VI.A.3.q. Female (**B**+R+A): tested with a male (**B**+R+A); 19 Black, 7 Red, 7 Albino.
(1) crossed with VI.A.1.d. (**B**+R+A); see above.

*VI.A.3.r. Female (**B**+R+A).
(1) crossed with male VI.C.3.a. (**B**+R+A); 3 Black, 2 Red, 3 Albino.

*VI.C.1.b. Male (**B**+R+A).

(1) crossed with female VI.C.1.f. (**B**+R+A); 41 Black, 15 Red, 18 Albino.

VI.C.1.c. Male (**B**+R+A): tested with Red: 33 Black, 20 Red.

(1) crossed with female VI.C.1.l. (**B**+R+A); 12 Black, 3 Red, 2 Albino.

VI.C.1.d. Female (**B**+R+A): tested with Reds carrying Albino; 49 Black, 51 Red, 35 Albino.

(1) crossed with male VI.A.1.a. (**B**+R); see above;

(2) crossed with male VI.A.3.d. (**B**+R); see above;

(3) crossed with male VI.A.3.c. (**B**+R+A); see above.

VI.C.1.f. Female (**B**+R+A): tested with Red carrying Albino; 32 Black, 23 Red, 23 Albino.

(1) crossed with male VI.C.1.b. (**B**+R+A); see above.

*VI.C.1.g. Female (**B**+R+A).

(1) crossed with male from VI.C.1. (**B**+R+A); 8 Black, 5 Red, 4 Albino.

VI.C.1.h. Female (**B**+R): tested with Red: 16 Black, 24 Red.

(1) crossed with male VI.A.1.e. (**B**+R+A); see above.

(2) crossed with male VI.C.3.b. (**B**+R+A); 8 Black, 4 Red.

VI.C.1.l. Female (**B**+R+A): tested with Red: 18 Black, 22 Red.

(1) crossed with male VI.C.1.c.; see above.

*VI.C.2.a. Male (**B**+R+A).

(1) crossed with female VI.C.2.f. (**B**+R+A); 7 Black, 2 Red, 7 Albino.

*VI.C.2.b. Male (**B**+R+A).

(1) crossed with female VI.C.2.g. (**B**+R+A); 10 Black, 4 Red, 7 Albino.

VI.C.2.e. Male (**B**+R+A).

(1) crossed with female VI.C.2.k. (**B**+R+A); 7 Black, 1 Albino;

(2) crossed with female VI.C.2.l. (**B**+R+A); 15 Black, 3 Red, 9 Albino.

VI.C.2.f. Female (**B**+R+A).
(1) crossed with a male from VI.C.2. (**B**+R+A); 4 Black, 1 Red, 7 Albino;
(2) crossed with male VI.C.2.a. (**B**+R+A); see above.

*VI.C.2.g. Female (**B**+R+A).
(1) crossed with male VI.C.2.b. (**B**+R+A); see above.

VI.C.2.k. Female (**B**+R+A): tested with Albino carrying Red; 17 Black, 1 Red, 3 Albino.
(1) crossed with male from VI.C.2. (**B**+R+A); 7 Black, 2 Red, 4 Albino;
(2) crossed with male VI.C.2.e. (**B**+R+A); see above.

*VI.C.2.l. Female (**B**+R+A).
(1) crossed with male VI.C.2.e. (**B**+R+A); see above.

*VI.C.3.a. Male (**B**+R+A).
(1) crossed with female VI.A.3.r. (**B**+R+A); see above.

VI.C.3.b. Male (**B**+R+A): tested with Red carrying Albino: 15 Black, 12 Red, 11 Albino.
(1) crossed with female VI.C.1.h. (**B**+R); see above;
(2) crossed with female VI.C.3.g. (**B**+R); 13 Black, 5 Red.

VI.C.3.d. Female (**B**+R): tested with Reds: 25 Black, 16 Red.
(1) crossed with male VI.A.3.c. (**B**+R+A); see above.

VI.C.3.e. Female (**B**+R+A): tested with Reds; 27 Black, 14 Red.
(1) crossed with male VI.A.3.d. (**B**+R); see above.

VI.C.3.g. Female (**B**+R): tested with Albino carrying Red; 13 Black, 15 Red.
(1) crossed with male VI.C.3.b. (**B**+R+A); see above.

* The animals marked with an asterisk had not been previously tested.

In each of the above instances *some red young were produced*, showing that the parents were all blacks carrying red and not one-dose blacks. These tests therefore are in favour of *Hypothesis II* being the correct one.

Cross C. F. 2. Generation. Reds.

Turning now to the Red F_2, according to *Hypothesis I* these are of two kinds, one with only one dose of red and no factor for albino (C C R), and two with only one dose of red and with the factor for albino (C c R).

There are three possible ways in which these reds could be mated together and these matings would give the following :—

(1) C C R × C C R
Male Gametes :— C R and C
Female ,, C R and C
Zygotes C R C R
C R C
C R C
C C

that is one C C R R, two C C R, one C C
,, ,, 3 reds and 1 albino.

(2) C c R × C c R
Male Gametes C R, C, c R, c
Female ,, C R, C, c R, c
Zygotes

C R C R	C C R	c R C R	c C R
C R C	C C	c R C	c C
C R c R	C c R	c R c R	c c R
C R c	C c	c R c	c c

That is 9 reds and 7 albinos.

(3) C C R × C c R
Male Gametes C R and C
Female ,, C R, C, c R, c
Zygotes

C R C R	C C R	c R C R	c C R
C R C	C C	c R C	c C

That is 6 reds and 2 albinos.

It will be seen that in each case, that is to say, *in whatever way the* *reds in this generation are mated, there would be albinos in the offspring.* Further, in each case, in addition to the usual imperfect-eyed albinos $\genfrac{}{}{0pt}{}{c\,R}{c\,R}$, $\genfrac{}{}{0pt}{}{c\,B}{c\,B}$, $\genfrac{}{}{0pt}{}{c\,B}{c\,R}$, all-whites of the same hypothetical constitution as the original "all-white" male from red stock $\genfrac{}{}{0pt}{}{C}{C}$ should occur, and if these resemble the original parent they will have perfectly formed eyes.

According to *Hypothesis II* the Reds can also be mated in three different ways. The results would be :—

(1) C C R R × C C R R

Gametes all C R

Zygotes all C C R R.

That is, all red.

(2) C c R R × C c R R

Male Gametes C R, c R

Female ,, C R, c R

Zygotes C C R R, C c R R, C c R R, c c R R

That is, 3 reds and 1 albino.

(3) C C R R × C c R R

Male Gametes C R

Female ,, C R and c R

Zygotes C C R R and C c R R

That is, all red.

In two of the instances therefore the offspring would be all red-eyed. in one instance there would be albinos in the brood.

Experiment has shown that when reds of the F_2 generation are mated together *some broods consist entirely of red-eyed young*, whilst others consist of reds and albinos. Further, the albinos when they occurred were of the usual imperfect-eyed type. Hypothesis II is therefore in agreement with the experimental facts, whilst Hypothesis I is not.

The following list shows the Red-eyed young and the matings made to prove their constitution.

VI.A.1.m. Male, *Pure Red* (Plate II).

Matings :—(1) with female p of its own brood, (**R**+A); 72 young, all Red (Plate IV, Fig. 11);

(2) with female q of its own brood, (**R**+A); 32 young, all Red (Plate IV, Fig. 10);

(3) with female IV.O (**B**+A); 39 young, all Black;

(4), (5) mated with 2 Albino females: ate them.

VI.A.1.n. Male, *Red carrying Albino.*
Matings :—(1) with female q of its own brood, (**R**+A); 63 young, 52 Red, 11 Albino (Plate IV, Fig. 9);
(2) with female VI.B. (**R**+A); 69 young, 50 Red, 19 Albino.

VI A.1.o. Male, *Pure Red.*
Matings :—(1) with female h of its own brood (**B**+R+A); (31 young, 17 Black, 14 Red);
(2) with female p of its own brood, (**R**+A); 40 young, all Red.

VI.A.1.p. Female, *Red carrying Albino.*
Matings :—(1) with male m of its own brood; (72 young, all Red) (Plate IV, Fig. 11);
(2) with male II.B. (**R**+A); (90 young, 66 Red, 24 Albino) (Plate IV, Fig. 12);
(3) with male o of its own brood; (40 young, all Red);
(4) with male VI.B.1.b. (**R**+A); 17 young, 16 Red, 1 Albino.

VI.A.1.q. Female, *Red carrying Albino.*
Matings :—(1) with male n of the same brood; (63 young, 52 Red, 11 Albino) (Plate IV, Fig. 9);
(2) with male m of the same brood; (32 young, all Red) (Plate IV, Fig. 10);
(3) with male c of the same brood, (Pure Black); (45 young, all Black) (Plate IV, Fig. 8).

Brood 2 of VI.A.

The 4 Red hatched died immature.

VI.A.3.t. Male, *Red carrying Albino.*
Matings :—(1) with female VI.A.2.l. (**A**+B+R); 6 young, 1 Red, 5 Albino;
(2) with female VI.B.3.g.; ate it;
(3) with female IV.V. (**B**+A); 12 young, 10 Black, 2 Albino;
(4) with female VI.C.3.d. (**B**+R); 25 young, 12 Black, 13 Red.

VI.A.3.u. Male, *Red carrying Albino.*
Matings :—(1) with female w of the same brood, (**R**+A); 48 young, 36 Red, 12 Albino;

Matings :—(2) with female x of the same brood, (Pure Red); 10 young, all Red;
(3) with female III.N. (**B**+A); 42 young, 32 Black, 10 Albino.

VI.A.3.v. Male, *Red carrying Albino.*
Matings :—(1) with female x of the same brood, (Pure Red); 28 young, all Red;
(2) with female w of the same brood, (**R**+A); 16 young, 10 Red, 6 Albino.

VI.A.3.w. Female, *Red carrying Albino.*
Matings :—(1) with male u of the same brood, (**R**+A); (48 young, 36 Red, 12 Albino);
(2) with male v of the same brood, (**R**+A); (16 young, 10 Red, 6 Albino);
(3) with male VI.C.3.c. (**B**+A); 17 young, 15 Black, 2 Albino.

VI.A.3.x. Female, *Pure Red.*
Matings :—(1) with male u of the same brood, (**R**+A); (10 young, all Red);
(2) with male v of the same brood, (**R**+A); (28 young, all Red);
(3) with male VI.C.2.r. (**A**+B+R); 34 young, 22 Black, 12 Red.

VI.C.1.m. Male, *Red carrying Albino.*
Matings :—(1) with female VI.A.1.f. (**B**+R+A); (71 young, 31 Black, 18 Red, 22 Albino);
(2) with female VI.A.1.g. (**B**+R+A); (22 young, 10 Black, 8 Red, 4 Albino).

VI.C.1.n. Male, *Red carrying Albino.*
Matings :—(1) with female d of the same brood, (**B**+R+A); (96 young, 37 Black, 35 Red, 24 Albino);
(2) with female e of the same brood, (Pure Black); (49 young, all Black).

VI.C.1.o. Male, *Red carrying Albino* (Plate IV, Figs. 3 and 6).
Matings :—(1) with female e of the same brood, (Pure Black); (42 young, all Black);
(2) with female d of the same brood, (**B**+R+A); (39 young, 12 Black, 16 Red, 11 Albino);
(3) with female VI.A.1.l. (**B**+R+A); (82 young, 37 Black, 24 Red, 21 Albino).

VI.C.1.p. Male, *Red carrying Albino.*

Matings :—(1) with female h of the same brood, (**B**+R); (40 young, 16 Black, 24 Red);

(2) with female f of the same brood, (**B**+R+A); (78 young, 32 Black, 23 Red, 23 Albino);

(3) with female VI.A.3.k. (**B**+A); (38 young, 27 Black, 11 Albino).

VI.C.2.m. Male, *Red carrying Albino.*

Matings :—(1) with female n of the same brood, (**R**+A); 5 young, 2 Red, 3 Albino.

VI.C.2.n. Female, *Red carrying Albino.*

Matings :—(1) with male m of the same brood; (5 young, 2 Red, 3 Albino);

(2) eaten by mate.

VI.C.2.o. Female, constitution unknown.

Matings :—(1) with male m of the same brood (**R**+A); eleven batches of eggs were laid, but no young were hatched; female died.

VI.C.3.m. Male, *Red carrying Albino.*

Matings :—(1) with female o of the same brood, (Pure Red); 48 young, all Red;

(2) with female r of the same brood, (**A**+R); 381 young, 181 Red, 200 Albino.

VI.C.3.n. Male, *Red. Albinism not known.*

Matings :—(1) with female d of the same brood, (**B**+R); (16 young, 13 Black, 3 Red).

These young all died immature, and it was therefore not possible to test the brood for albinism.

VI.C.3.o. Female, *Pure Red.*

Matings :—(1) with male m of the same brood, (**R**+A); (48 young, all Red);

(2) with male q of the same brood, (**A**+R); 36 young, all Red.

VI.B.1.a. Male, *Pure Red.*

Matings :—(1) with female f of the same brood, (**R**+A); 29 young, all Red;

(2) with female j of the same brood, (Pure Red); 37 young, all Red;

(3), (4) with a Black female and an Albino female, both of which it ate.

VI.B.1.b. Male, *Red carrying Albino.*

Matings :—(1) with female g of the same brood, (Pure Red) ; 49 young, all Red ;

(2) with female VI.A.1.p. (**R**+A) (17 young, 16 Red, 1 Albino).

VI.B.1.c. Male, *Red carrying Albino.*

Matings :—(1) with female h of the same brood, (**R**+A) ; 21 young, 17 Red, 4 Albino ;

(2) with female g of the same brood, (Pure Red) ; 11 young, all Red.

VI.B.1.d. Male, *Red carrying Albino.*

Matings :—(1) with female j of the same brood, (Pure Red) ; 55 young, all Red ;

(2) with female f of the same brood, (**R**+A) ; 51 young, 37 Red, 14 Albino ;

(3) with female IV.S. (**B**+A) ; 18 young, 13 Black, 5 Albino.

VI.B.1.e. Male. *Red. Albinism not known.*

Matings :—(1) with female from the same stock as R.1. male (see Plate II and p. 324), (Pure Red) ; 16 young, all Red.

Only two of these survived to maturity, and were mated with Albino females ; 33 young were produced, 19 Black, and 14 Red, no albinos.

VI.B.1.f. Female, *Red carrying Albino.*

Matings :—(1) with male a of the same brood, (Pure Red) ; (29 young, all Red) ;

(2) with male d of the same brood, (**R**+A) ; (51 young, 37 Red, 14 Albino) ;

(3) with a male (from Brood 1 of VI.A.1. female h), (**R**+A) ; 27 young, 15 Red, 12 Albino ;

(4) with male e of same brood ; ate it.

VI.B.1.g. Female, *Pure Red.*

Matings :—(1) with male b of the same brood, (**R**+A) ; (49 young, all Red) ;

(2) with male c of the same brood, (**R**+A) ; (11 young, all Red) ;

(3) with male IV.K. (**B**+R+A) ; 9 young, 2 Black, 7 Red.

VI.B.1.h. Female, *Red carrying Albino.*

Matings :—(1) with male c of the same brood, (**R**+A) ; (21 young, 17 Red, 4 Albino).

VI.B.1.j. Female, *Pure Red.*

Matings :—(1) with male d of the same brood, (**R**+A) ; (55 young, all Red) ;

(2) with male a of the same brood, (Pure Red) ; (37 young, all Red).

VI.B.1.k. Female, *Red.* Albinism not known.

Matings :—(1) with male m of the same brood, (**A**+R) ; four months in the bowl, six matings, no young hatched, female died.

VI.B.1.l. Male, *Red.* Albinism not known.

Put with a female from the same stock as R.1. male (Plate II), no mating.

VI.B.2.a. Male, *Red carrying Albino.*

Matings :—(1) with female f of the same brood, (**R**+A) ; 8 young, all Red ;

(2) with female p of the same brood, (Red, albinism not known) ; 2 young, Red ;

(3) with female e of the same brood, (**R**+A) ; 8 young, 6 Red, 2 Albino ;

(4) with female v of the same brood, (**A**+R) ; 38 young, 35 Red, 3 Albino ;

(5) with female u of same brood, (**A**+R) ; 48 young, 24 Red, 24 Albino (Plate IV, Fig. 18).

VI.B.2.b. Male, *Red carrying Albino.*

Matings :—(1) with female g of the same brood, (Pure Red) ; 87 young, all Red ;

(2) with female w of the same brood, (**A**+R) ; 222 young, 118 Red, 104 Albino.

VI.B.2.c. Male, *Red carrying Albino.*

Matings :—(1) with female h of the same brood, (**R**+A) ; 11 young, 7 Red, 4 Albino ;

(2) with female g of the same brood, (Pure Red) ; 21 young, all Red.

VI.B.2.d. Male, *Red carrying Albino.*

Matings :—(1) with female r of the same brood ; 7 young, all Red ;

(2) with female e of the same brood, (**R**+A) ; 25 young, 21 Red, 4 Albino ;

(3) with female VI.A.2.c. (**B**+R) ; (27 young, 16 Black, 11 Red).

VI.B.2.e. Female, *Red carrying Albino.*

Matings :—(1) with male a of the same brood, (**R**+A) ; (8 young, 6 Red, 2 Albino) ;
(2) with male d of the same brood, (**R**+A) ; (25 young, 21 Red, 4 Albino) ;
(3) with male III.D. (**B**+A) ; 19 young, 11 Black, 8 Albino ;
(4) with male VI.C.3.b. (**B**+R+A) ; (38 young, 15 Black, 12 Red, 11 Albino) ;
(5) with male VI.B.1.m. (**A**+R) ; (87 young, 50 Red, 37 Albino).

VI.B.2.f. Female, *Red carrying Albino.*

Matings :—(1) with male a of the same brood, (**R**+A) ; (8 young, all Red) ;
(2) with male VI.C.2.q. (**A**+B+R) ; (20 young, 6 Black, 5 Red, 9 Albino).

VI.B.2.g. Female, *Pure Red.*

Matings :—(1) with male b of the same brood, (**R**+A) ; (87 young, all Red) ;
(2) with male c of the same brood, (**R**+A) ; (21 young, all Red) ;
(3) with male VI.C.2.d. (Pure Black) ; (23 young, all Black) ;
(4) with male from Brood 1 of male III.B. (**A**+B) ; 54 young, all Black.

VI.B.2.h. Female, *Red carrying Albino.*

Matings :—(1) with male c of the same brood, (**R**+A) ; (11 young, 7 Red, 4 Albino).

VI.B.2.j. Female, *Pure Red.*

Matings :—(1) with male VI.A.2.g. (**A**+R) ; (26 young, all Red).

VI.B.2.k. Female, *Red carrying Albino.*

Matings :—(1) with male VI.A.2.j. (**A**+R) ; (38 young, 22 Red, 16 Albino) ;
(2) with male VI.A.2.h. (**A**+B+R) ; (16 young, 6 Black, 2 Red, 8 Albino).

VI.B.2.l. Female, *Red carrying Albino.*

Matings :—(1) with male VI.C.2.p. (**A**+R) ; (6 young, 3 Red, 3 Albino) ;
(2) with male VI.C.2.u. (**A**+R) ; (1 young, Albino).

VI.B.2.m. Female, *Red carrying Albino.*
Matings :—(1) with male VI.C.2.s. (**A**+B+R) ; (9 young, 3 Black, 2 Red, 4 Albino).

VI.B.2.n. Female, *Pure Red.*
Matings :—(1) with male VI.A.3.z. (**A**+B+R) ; (15 young, 10 Black, 5 Red).

VI.B.2.o. Female, *Pure Red.*
Matings :—(1) with male VI.A.3.aa. (**A**+R) ; (12 young, all Red).

VI.B.2.p. Female, *Red.* Albinism not known.
Matings :—(1) with male a of the same brood, (**R**+A) ; (2 young, Red).

VI.B.2.q. Female, *Red.* Albinism not known.
Matings :—(1) with male VI.A.3.y. (**A**+B); (1 young, Black).

VI.B.2.r. Female, *Red.* Albinism not known.
Matings :—(1) with male d of the same brood, (**R**+A) ; (7 young, all Red).

One male, mated with female v, and 5 females which reached maturity and mated, were eaten by their mates. One died immature.

VI.B.3.a. Male, *Red carrying Albino.*
Matings :—(1) with female VI.C.3.u. (**A**+B+R) ; (47 young, 15 Black, 13 Red, 19 Albino) ;
(2) with female VI.A.2.m. (**A**+B+R) ; 33 young, 6 Black, 14 Red, 13 Albino.

VI.B.3.b. Male, *Red carrying Albino.*
Matings :—(1) with female VI.C.3.w. (**A**+R) ; (31 young, 19 Red, 12 Albino) ;
(2) with female VI.C.3.f. (**B**+A) ; (25 young, 21 Black, 4 Albino).

VI.B.3.c. Male, *Red carrying Albino.*
Matings :—(1) with female VI.C.3.x. (**A**+B+R) ; (19 young, 7 Black, 4 Red, 8 Albino).

VI.B.3.d. Male, *Red.* Not proved.
Matings :—(1) with Albino female VI.C.3.t. ;
(2) with Red female of the same brood ;
(3) with Albino female I.G.1.c. ; all of which it ate ;
(4) with Albino female VI.A.2.m. Died.

VI.B.3.e. Female, *Pure Red.*
Matings :—(1) with a Red male of the same brood ; 2 young, Red ;

Matings :—(2) with male VI.A.2.a. (**B**+R+A) ; (20 young, 8 Black, 12 Red) ;
(3) with male VI.C.2.u. (**A**+R) ; (24 young, all Red).

VI.B.3.f. Female, *Red carrying Albino.*
Matings :—(1) with male VI.C.2.c. (**B**+A) ; (6 young, 5 Black, 1 Albino).

VI.B.3.g. Female. *Red. Not proved.*
Matings :—(1) with Black male VI.A.2.b. ; (5 young, Black) ;
(2) with a Red male VI.A.3.t. ; was eaten.

4 others, females, reached maturity, mated and died ; one died immature.

VI.B.4.a. Male, *Red carrying Albino.*
Matings :—(1) with Black female (from Brood 1 of female IV.N.) ; 8 young, 7 Black, 1 Albino ;
(2) with female c of the same brood, (**R**+A) ; 22 young, 17 Red, 5 Albino.

VI.B.4.b. Male, *Red carrying Albino.*
Matings :—(1) with female d of the same brood, (Pure Red) ; 13 young, Red ;
(2) with female g of the same brood, (**A**+R) ; 132 young, 71 Red, 61 Albino.

VI.B.4.c. Female, *Red carrying Albino.*
Matings :—(1) with male a of the same brood, (**R**+A) ; (22 young, 17 Red, 5 Albino).

VI.B.4.d. Female, *Pure Red.*
Matings :—(1) with a Red male of the same brood ; 1 young, Red ;
(2) with male b of the same brood ; (13 young, Red) ;
(3) with a Red male (from Brood 3 of female III.Q) ; 51 young, all Red.

VI.B.4.e. Female. *Red.* Constitution unknown.

In all, 3,443 young were produced. The numbers from the different matings are as follows :

Red by **R** ; **R**+A ; and **A**+R ; 709 young, all Red.
Red carrying Albino by **R**+A ; and **A**+R ; 883 Red, 582 Albino.
Red and **R**+A by Black ; 258, all Black.
Red and **R**+A by **B**+R ; 135 Black, 115 Red.

Red carrying Albino by **B**+A and **A**+B ; 141 Black, 44 Albino.
Red carrying Albino by **B**+R+A and **A**+B+R ; 217 Black, 177 Red, 182 Albino.

To sum up, 60 red-eyed animals were tested, 49 gave definite results, 36 proving to be Red with the albino factor, and 13 Pure Red. Theory demands 36·6 Red with albino, 12·2 Pure Red.

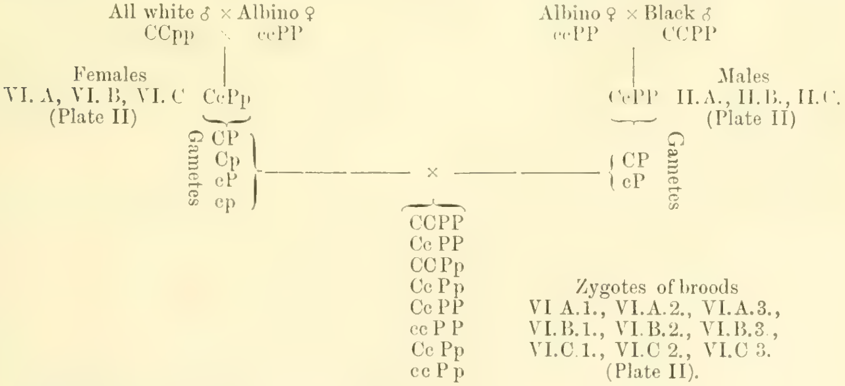
These results are in full agreement with *Hypothesis II* and not in agreement with *Hypothesis I*.

Cross C. F.2. Generation. Albinos.

A final test of the two hypotheses would be obtained by testing the F_3 albinos got by crossing F_2 coloured parents. Amongst these F_3 albinos animals with the constitution $\frac{C}{C}$ like the original all-white male parent should occur if *Hypothesis I* were true. If therefore we make many crosses amongst the albinos of this generation we ought to find some pairs which would give all coloured offspring. If these are not produced it will be an additional proof that *Hypothesis II* is the right one. We have made 18 matings of this character, and they yielded a total of 588 young, all of them albino.*

---

* In all the animals referred to in this paper as "albino," the eyes had the irregular, degenerate form figured on Plate VII, Fig. 4. If we take the view that, in the absence of red and black pigment, the regular form is in itself sufficient to distinguish the "all white" eye (Plate VII, Fig. 7) from the imperfectly shaped "albino" eye, the following statement, the form of which we owe to Prof. R. C. Punnett, who has been good enough to read this paper in proof, puts the argument against our Hypothesis I in a brief form. The letter P must be understood to represent the factor for either red or black pigment, p the absence of such a factor. Hypothesis I. That two complementary colour factors are concerned, of which the "albino" female contains one, viz. P, and the "all white" male the other, viz. C.


All white ♂ × Albino ♀
CCpp ccPP
Albino ♀ × Black ♂
ccPP CCPP
Females
VI. A, VI. B, VI. C
(Plate II)
CcPp
CcPP
Males
II.A., II.B., II.C.
(Plate II)
Gametes
CP
Cp
cP
cp
×
CP
cP
Gametes
CCPP
Cc PP
CCPp
Cc Pp
Cc PP
cc P P
Cc Pp
cc P p
Zygotes of broods
VI A.1., VI.A.2., VI.A.3.,
VI.B.1., VI.B.2., VI.B.3.,
VI.C.1., VI.C 2., VI.C 3.
(Plate II).

Mated among themselves the chances of Pp zygotes coming together are 16 in 64, i.e. 1 in 4, and in such cases "all-white" eyes should appear in ratio 1 : 3. Amongst the blacks 109 such matings have been made, amongst the reds 40, and amongst the albinos 27, making a total of 176 such matings, and no "all-white" eyes of perfect form appeared. Hence Hypothesis I is not valid here.

The Albinos of VI.A. may be taken as a fairly accurate record of the proportions found, most of them, 13 out of 15, having survived to maturity. Of these 3 carried Black only, 3 Red only, and 7 carried both Black and Red.

VI.A.1.r. Male, *Albino carrying Black only.*
Matings :—(1) with female VII.C.3.a. (Plate V) (Red no-white) ; 36 young, all Black (Plate IV, Fig. 17) ;
(2) with female VI.A. (its female parent) (**B**+R+A) ; 1 young, Black ;
(3) with female from the Pure Red Stock ; 23 young, all Black (Plate IV, Fig. 16).

VI.A.1.s. Male, *Albino carrying Black only.*
Matings :—(1) with female VII.C.3.b. (Plate V) (Red no-white) ; 57 young, all Black.

VI.A.1.t. Male, *Albino carrying Black and Red.*
Matings :—(1) with female from No-white Stock (Red no-white) ; 34 young, 17 Black, 17 Red ;
(2) with female VI.C. (**B**+R+A) ; 14 young, 8 Black, 6 Albino.

VI.A.2.g. Male, *Albino carrying Red only.*
Matings :—(1) with female VI.B.2.j. (Pure Red) ; 26 young, all Red ;
(2) with female VI.C.3.h. (Pure Black) ; 29 young, all Black.

VI.A.2.h. Male, *Albino carrying Black and Red.*
Matings :—(1) with female m of the same brood, (**A**+B+R) ; 25 young, all Albino ;
(2) with female VI.B.2.k. (**R**+A) ; 16 young, 6 Black, 2 Red, 8 Albino.

VI.A.2.j. Male, *Albino carrying Red only.*
Matings :—(1) with VI.B.2.k. (**R**+A) ; 38 young, 22 Red, 16 Albino ;
(2) with female m of the same brood, (**A**+B+R) ; 1 young, Albino.

VI.A.2.k. Female, *Albino carrying Black and Red.*
Matings :—(1) with male a of the same brood, (**B**+R+A) ; (7 young, 2 Black, 1 Red, 4 Albino) ;
(2) with male VI.A.3.aa. (**A**+R) ; 42 young, all Albino ;

Matings :—(3) with male II.B. (**R**+A) ; 146 young, 33 Black, 44 Red, 69 Albino.

VI.A.2.l. Female, *Albino carrying Black and Red.*

Matings :—(1) with male VI.A.3.t. (**R**+A) ; (6 young, 1 Red, 5 Albino).

The female died after extruding this brood ; the proof of her constitution was obtained by mating the young, when mature, together and with mates of proved constitution. The red one was a male, the albinos were one male and four females. The Albino male and one female mated ; 9 young, all Albino. The female was then mated with the Red male, and gave in 38 young, 13 Black, 8 Red, 17 Albino. (The albino male mated with a Pure Red female had 31 young, all Red.)

VI.A.2.m. Female, *Albino carrying Black and Red.*

Matings :—(1) with an Albino male of the same brood ; 5 young, all Albino ;
(2) with male h of the same brood, (**A**+B+R) ; (25 young, all Albino) ;
(3) with male j of the same brood, (**A**+R) ; (1 young, Albino ;)
(4) with male VI.B.3.d. ; no results ;
(5) with male VI.B.3.a. (**R**+A) ; (33 young, 6 Black, 14 Red, 13 Albino).

VI.A.3.y. Male *Albino carrying Black only.*

Matings :—(1) with female VI.B.2.q. (Red, albinism not known) ; 1 young, Black ;
(2) with female I.E.2.f. (**R**+A) ; 15 young, 3 Black, 12 Albino.

VI.A.3.z. Male, *Albino carrying Black and Red.*

Matings :—(1) with female VI.B.2.n. (Pure Red) ; 15 young, 10 Black, 5 Red.

VI.A.3.aa. Male, *Albino carrying Red only.*

Matings :—(1) with female VI.B.2.o. (Pure Red) ; 12 young, all Red ;
(2) with female VI.A.2.k. (**A**+B+R) ; (42 young, all Albino) ;
(3) with female VI.A.2.d. (**B**+A) ; (18 young, 8 Black, 10 Albino) ;
(4) with female VI.A.2.e. (**B**+A) ; (29 young, 13 Black, 16 Albino) ;

Matings :—(5) with female VI.A.2.f. (**B**+A) ; (30 young, 12 Black, 18 Albino).

VI.A.3.bb. Female, *Albino carrying Black and Red.*

Matings :—(1) with male I.E.2.a. (**R**+A) ; 12 young, 3 Black, 2 Red, 7 Albino ;

(2) with male b of the same brood (**B**+A) ; (14 young, 2 Black, 12 Albino).

VI.C.1.q. Male, *Albino carrying Red only.*

Mating :—(1) with female I.E.2.d. (Red) ; 13 young, all Red.

VI.C.2.p. Male, *Albino carrying Red only.*

Matings :—(1) with female VI.B.2.l. (**R**+A) ; 6 young, 3 Red, 3 Albino.

Five of these young came to maturity, Red, one male and one female, and Albino, two males and one female ; these were mated together to see if the Albinos carried the Black factor ; 203 young were produced, 116 Red, and 87 Albino ; no Black appeared. (One of the Albino males was mated with female VI.C.3.j.)

VI.C.2.q. Male, *Albino carrying Black and Red.*

Matings :—(1) with female VI.B.2.f. (**R**+A) ; 20 young, 6 Black, 5 Red, 9 Albino.

VI.C.2.r. Male, *Albino carrying Black and Red.*

Matings :—(1) with female I.G.1.c. (**A**) ; 49 young, all Albino ;

(2) with female VI.A.3.x. (Pure Red) ; (34 young, 22 Black, 12 Red).

VI.C.2.s. Male, *Albino carrying Black and Red.*

Matings :—(1) with female VI.B.2.m. (**R**+A) ; 9 young, 3 Black, 2 Red, 4 Albino.

VI.C.2.t. Male, *Albino carrying Black and Red.*

Matings :—(1) with two Red females which it ate ;

(2) with female I.E.2.e. (Pure Red) ; 27 young, 15 Black, 12 Red.

VI.C.2.u. Male, *Albino carrying Red only.*

Matings :—(1) with Red female which it ate ;

(2) with female k of the same brood, (**B**+R+A) ; (21 young, 17 Black, 1 Red, 3 Albino) ;

(3) with female VI.B.2.l. (**R**+A) ; 1 young, Albino ;

Matings :—(4) with female VI.B.3.e. (Pure Red) ; 21 young, all Red ;
(5) with female VI.C.3.g. (**B**+R) ; 28 young, 13 Black, 15 Red.

One other reached maturity, a female, which died before its constitution could be tested.

VI.C.3.p. Male, *Albino carrying Red only.*

Matings :—(1) with female r of the same brood, (**A**+R) ; 11 young, all Albino ;
(2) with female j of the same brood, (**B**+A) ; (31 young, 14 Black, 17 Albino) ;
(3) with female VI.B.2.j. (Pure Red) ; 17 young, all Red).

VI.C.3.q. Male, *Albino carrying Red only.*

Matings :—(1) with female u of the same brood, (**A**+B+R) ; 11 young, all Albino ;
(2) with Albino female v of the same brood (constitution unknown) ; 30 young, all Albino ;
(3) with female t of the same brood, (**A**) 14 young, all Albino ;
(4) with female o of the same brood, (Pure Red) ; (36 young, all Red).

VI.C.3.r. Female, *Albino carrying Red only.*

Matings :—(1) with male p of the same brood (**A**+R) ; (11 young, all Albino) ;
(2) with male m of the same brood, (**R**+A) ; 381 young, 181 Red, 200 Albino.

VI.C.3.s. Female, *Albino carrying Red only.*

Matings :—(1) with a male descended from the same stock as R.1. (see male II.B. p. 284) (Pure Red) ; 5 young, all Red.

VI.C.3.t. Female, *Albino.* Constitution unknown.

Matings :—(1) with male q of the same brood, (**A**+R) ; (14 young, all Albino) ;
(2) with Red male VI.B.3.d. ; eaten.

VI.C.3.u. Female, *Albino carrying Black and Red.*

Matings :—(1) with male q of the same brood (**A**+R) ; (11 young, all Albino) ;
(2) with male VI.B.3.a. (**R**+A) ; 47 young, 15 Black, 13 Red, 19 Albino.

VI.C.3.v. Female, *Albino.* Constitution unknown.

Matings :—(1) with male q of the same brood, (**A**+R); (30 young, all Albino).

All the young died without mating.

VI.C.3.w. Female, *Albino carrying Red only.*

Matings :—(1) with male VI.B.3.b. (**R**+A); 31 young, 19 Red, 12 Albino.

VI.C.3.x. Female, *Albino carrying Black and Red.*

Matings :—(1) with male VI.B.3.c. (**R**+A); 19 young, 7 Black, 4 Red, 8 Albino.

VI.B.1.m. Male, *Albino carrying Red.*

Matings :—(1) with female k of the same brood; no results;

(2) with female VI.B.2.e. (**R**+A); 87 young, 50 Red, 37 Albino.

VI.B.2.s. Male, *Albino.*

Matings :—(1) with Albino female w of the same brood; 38 young, all Albino.

VI.B.2.t. Male, *Albino carrying Red.*

Matings :—(1) with Albino female u of the same brood; 70 young, all Albino;

(2) with a female I.E.2.e. (Pure Red); 50 young, all Red;

(3) with female VI.C.3.e. (**B**+R+A); (28 young, 13 Black, 4 Red, 11 Albino);

(4) with a female of brood 1 of female VI.A.1.h (**B**+R); 23 young, 7 Black, 16 Red;

(5) with a female (from a mating in the first brood from male II.D.1.k.) (Colourless); 90 young, all Albino.

VI.B.2.u. Female, *Albino carrying Red.*

Matings :—(1) with male t of the same brood; 70 young, all Albino;

(2) with male a of the same brood, (**R**+A); (48 young, 24 Red, 24 Albino) (Plate IV, Fig. 18).

(3) with male VI.A.1.d. (**B**+R+A); (24 young, 1 Black, 3 Red, 20 Albino).

VI.B.2.v. Female, *Albino carrying Red.*

Matings :—(1) with male from Pure Red Stock; 49 young, all Red;

Matings :—(2) with male a of the same brood, (**R**+A) ; (38 young, 35 Red, 3 Albino) ;
(3) with a Red male of the same brood which it ate ;
(4) with male VI.A.3.h. (**B**+A) ; (92 young, 52 Black, 40 Albino) ;
(5) with male VI.A.3.e. (Pure Black) ; (19 young, all Black) ;
(6) with male VI.C.2.d. (Pure Black) ; (21 young, all Black) ;
(7) with a Black male from a brood of VI.C.2.d × j. ; 2 young, Black.

VI.B.2.w. Female, *Albino carrying Red.*

Matings :—(1) with male s of the same brood ; (38 young, all Albino) ;
(2) with male b of the same brood (**R**+A), (222 young, 118 Red, 104 Albino).

VI.B.3.h. Female, *Albino.*

Matings :—(1) with an Albino male I.C.2.d. ; one brood, all Albino ; two survived and mated, producing 228 young, all Albino.

VI.B.4.f. Female, *Albino.*

Matings :—(1) with an Albino male (from Brood 3 of male VI.C.2.r.) ; eggs laid ; female eaten.

VI.B.4.g. Female, *Albino carrying Red.*

Matings :—(1) with an Albino male, a, from Brood 2 of male VI.C.1.b. ;
(2) with male b of same brood (**R**+A) : (132 young, 71 Red, 61 Albino).

Classes in F_2 Generation.

According to *Hypothesis II*, which has proved to be in agreement with the facts so far ascertained, there should be in the F_2 generation, resulting from the mating of two blacks both carrying red and albino, the following different kinds in the proportions shown :—

Blacks.

	Constitution.	Number.
Pure Black	C C B B	1
Black carrying Albino	C c B B	2
Black carrying Red	C C B R	2
Black carrying Red and Albino	C c B R	4

	Constitution.	Number.
Reds.		
Pure Red	C C R R	1
Red carrying Albino	C c R R	2
Albinos.		
Albino carrying Black	c c B B	1
Albino carrying Red	c c R R	1
Albino carrying Black and Red	c c B R	2

As a result of breeding tests, made either within the generation, or by crossing with known pure reds, all these classes have been proved to exist amongst the offspring of this generation, the actual numbers obtained for the blacks, reds and albinos being given on pp. 302, 317 and 318 respectively.

The results recorded in this section afford further proof of the fact set out in Section I that the imperfect albino eye behaves in inheritance in accordance with the theory formulated by Bateson and Punnett for coat-colour in mice, etc., which assumes in addition to the factors for the individual colours the existence of a factor (C), which must be present if the colour characters are to become visible.

Experiments with the Original Stock (p. 287).

The fact that the absence of coloured retinal pigment in the "all-white" perfect-eyed animals derived from red stock is a somatic character and not hereditary receives some slight support from further breeding experiments which were carried out with the original stock from which the animals came. These experiments give no indication that the abnormality is latent in the stock.

The two all-white specimens had occurred in two succeeding broods from a pair of red-eyed animals (see former paper, p. 45), all the other offspring of which were normal red-eyed animals. Two of these red-eyed offspring survived and 3 young (which reached maturity) were obtained by mating them together. These three were one male and two females, and their eyes, though distinctly red, were much paler in colour than usual, and in other ways not quite normal. The male mated with both the females. Altogether 21 young were obtained, all with normal bright red eyes, and from their matings 17 similar young were produced in the next generation. The 2 females were also mated with the male II.B. (p. 284), a red carrying albino. One female (14.a.) had 29 normal red-eyed young, and the other (14.b.) had 30. Two pairs of these young were mated together; the one pair had a brood of 17 red, and 5 albino all of the usual imperfect form, and the other pair had

39 red-eyed young in three broods. The experiment was not carried further.

The "Part-white" Eye.

The "Part-white" animals referred to in the former paper, p. 43 (Fig. 7), were also investigated, as it appeared probable that the abnormality might be related to that of the "All-white" perfect eye.

In the "part-whites," the eye was of perfect form, the chalk-white accessory pigment was always present, and most of the ommatidia were normal, with black or red retinal pigment developed; some of the ommatidia, however, were quite colourless, thus giving the effect of a patch of white on the eye.

The brood in which the "part-whites" first appeared consisted of 21 young, 13 black and 8 red. Of the red, 4 survived to maturity, 2 being part-white, male and female. The left eye of this male was figured (Fig. 7 in former paper), in the right eye two or three ommatidia were colourless, and on the inner side two ommatidia were separated from the ommateum, one pigmented and one unpigmented. The other "part-white," a female, had a cluster of 9 colourless ommatidia in the right eye and 5 in the left. These two mated several times, but no eggs were laid, and the female died. The male was then mated with a normal red-eyed female and had 30 young, all normal red-eyed animals. These died before reaching maturity.

The male was then mated with a Pure Black female, also a part-white, with a large patch of white on the upper side of the ommateum of the left side, and a small patch in the same position on the right side. This female came from wild stock brought in on July 14, 1915, and left to breed till February 11, 1916. When examined on that date, 60 young were found, 59 normal black-eyed, and the "part-white" female just mentioned.

The result of the mating was a brood of 22 young, all black-eyed. They were left to mate together and on October 3, 1916, 44 young were found, 22 black and 22 red, all normal-eyed.

These young were left to mate together and on February 22nd, 1917, the pots were examined. There were then present 73 young, 36 black and 37 red, all normal-eyed.

It seems certain therefore that the "part-white" character is not inherited.

SECTION III. THE NO-WHITE EYE
(Plate V).

As was mentioned in the former paper (p. 21), a mutation occurred in which the superficial chalk-white, extra-retinal pigment that forms a reticulation in which the ommatidia lie was entirely absent. This was called the " no-white " eye, and a black one was figured (Plate I, Fig. 6). A red one is figured in Plate VII, Fig. 5, of this paper.

The chalk-white extra-retinal pigment is much less resistant to alcohol and formalin than the black or red retinal pigment, quickly disappearing when placed in either of these liquids. It may be noted here, also, that the red retinal pigment is more easily dissolved by alcohol than the black, the latter being practically insoluble.

Animals occur in which the white pigment is present in the eye on one side and absent in that of the other. For details of experiments with these see p. 340.

Origin of Experimental Stock.

The " no-whites " with which most of the experiments have been made had the following history :

A pure black male from Chelson Meadows, which had been tested by mating with two wild females and with two other red females, and had given normal results, was mated with a pure red female (a descendant of the fourth brood of Female A of the former paper, p. 22) and had a large family (Family K, in former paper, p. 31). Of this family 24 survived, 5 males and 19 females, all normal-eyed hybrid blacks ; the young from their matings are now called " VII." At least 6 of these females when mated with males from the same family gave some " no-white " young, both black and red. Details are given in the former paper, p. 44.

Proof that " no-white," i.e. the absence of white pigment, behaves as a Mendelian recessive to the presence of white pigment.

One of the red " no-whites " from K family (VII, D.) was mated with a black male from the ordinary hybrid stock (Plate V, Fig. 2). There were 29 young, 12 black and 17 red, all normal-eyed, showing that the presence of white pigment is dominant, and its absence in the " no-white " eye is recessive.

An F_2 brood got by mating together two of the red young ones from the first brood (male e and female g) gave 3 " no-whites " to 13 normal, showing that the abnormality behaved in a Mendelian way and both the red-eyed animals carried the factor for no-white. In other broods, which were not examined immediately on extrusion, (1) red mated with red (male e and female f) gave 11 normal reds and 2 no-white reds ; (2) red mated with red (male e with females f and g) gave 12 normal reds and 5 no-white reds ; (3) two black females, 3 red females, and 2 red males belonging to this F_2 generation from the second brood (VII.D.2), left together in the same bowl gave

7 normal blacks, 4 no-white blacks.
11 ,, reds 3 ,, ,, reds.

The proportions are here however not significant, as red may have mated with red, as well as red with black.

Two other experiments give direct evidence of the dominance of normal white pigment over its absence in no-white eyes.

(1) A Red male (VII.E.) with both eyes no-white (**RN.**), from K family was mated with a Black carrying the factor for red (**B**+R), and there resulted a brood of 14, all normal-eyed, 7 black (**B**+R+N) and 7 red (**R**+N). When the young ones were mated together, " no-whites " both red and black appeared in the next generation.

(2) A Black male (III.J.) carrying the factors for Red and Albino was mated with a Black no-white female (pp. 280, 329) and had 92 young in four broods, all normal black-eyed.

That these no-white animals behave as simple recessives is illustrated by further matings which will now be described.

A brood resulting from the mating together of two of the hybrid blacks (**B**+R) of K family (Plate V, Fig. 1) consisted of 9 normal black-eyed young, 1 normal red-eyed and 5 black no-whites (VII). Three of these survived to maturity, 2 normal black-eyed females and one black no-white male. The male A mated with each female (B and C) in turn. With female C there were 26 young in three broods, 18 black and 8 red. The blacks consisted of 9 normal blacks, and 9 with no-white on both sides. The 8 red were 2 normal and 6 no-white on both sides.

From this it follows that both the male A and the female C were hybrids as regards red and black.

The male when mated with female B gave 42 young in four broods, all with black eyes, 25 being normal-eyed and 17 being no-whites. Female B is therefore pure black as regards retinal colour.

Both female C and female B in these matings behave as though they were hybrids for the character " no-white." Their no-white offspring when mated together give all no-white young. Thus a male and a female Black no-white (in brood B.1.) gave 3 black no-whites, a similar pair (in brood B.2.) gave 10 black no-whites. A male and a female, both Red no-whites (in brood C.2.) mated together gave 11 red no-whites.

A Black no-white male mated with a Red no-white female in the same brood (C.2.) gave 13 black no-white young. (This Black no-white therefore did not contain the factor for red.)

Brood C.1.b.1., the offspring of a black no-white male (b) with a red female (c) both from brood C.1., gave 1 normal black, 3 no-white blacks, and 2 no-white reds, which is explained by supposing that the black no-white male carries red. and the red female carries the factor for "no-white."

Other illustrations are the following :—

(1) The Red no-white male VII.E. (already used in Experiment (1) referred to on p. 327, where it was mated with a hybrid black female) was mated with a Red no-white female VII.F. of his own stock (Plate V, Fig. 3) and had 26 young in three broods, all red no-whites.

(2) The Red no-white female VII.F. was then mated with the Black no-white male (VII.A., see Fig. 1, Pl. V) and had two broods, with 63 in all, 34 being Black no-whites and 29 Red no-whites. This confirms the hybrid (**B**+R) character of the no-white male, which had already been shown in Fig. 1.

(3) A Black male (**BN**.) and a Red female (**RN**.), both no-whites, out of the same brood from K stock (VII. G and H), gave in one brood 26 young, 13 Black no-whites and 13 Red no-whites.

FURTHER INSTANCES OF "NO-WHITE" EYES ARISING.

In the case of the animals already described with which most of the experiments on the inheritance of no-white eyes were made, the mutation appeared in the hybrid stock. Another instance of a similar origin also occurred and was referred to in the former paper, p. 44. In the A family 7 animals out of 93 surviving produced some no-whites amongst their young. Altogether there were 277 of these young, and of these 126 showed some abnormality in the white extra-retinal pigment. In five cases (four black and one red) it was entirely absent in both eyes ; in five other cases (four black and one red) it was entirely absent from the eye of one side only, being normal in the other eye. In the other 116 the white pigment was very much reduced in amount and the reticulation was much broken up. In extreme cases there were only a few bars of white remaining. This gradual disappearance of the white pigment is an interesting feature, and might with advantage be studied further by means of definite breeding experiments. Other instances of a similar kind will be mentioned later.

No-white eyes have also originated independently of those described above, from wild stock which had not been crossed with red-eyed animals.

From a number of animals brought in from Chelson Meadow on February 11, 1915, certain pairs already mated in the open were put in separate finger-bowls. In the descendants of two of these pairs, no-white eyes have occurred. The pairs and their offspring will be considered separately.

(1) Pair V. In this pair the female had the white pigment very much reduced, the reticulation was perfect but the lines of white were very thin and thread-like. She was mated with a normal-eyed male, and had a fairly large brood which was not examined when young. Of this brood four reached maturity, three males and one female. One of the males mated with the female. The eyes of this male were examined and the white reticulation though perfect was so thin that it required microscopical examination with a 1-inch power to trace it. The eyes of the female were not examined, the male having devoured her after the extrusion of the brood. The brood numbered 13; 5 had a white reticulation which could just be seen under a hand-lens; 6 had eyes like the male parent, in which the reticulation could only be seen with a microscope; 2 had no reticulation and were typical no-whites. All the individuals of this brood were left together in the same finger-bowl, where they remained for some months. At the end of the time 6 very small young were found, all the other animals having died as the conditions in the bowl had become unhealthy. Of the 6 young ones, three had no-white eyes on both sides, one had no-white on the left side and very faintly marked reticulation on the right. The other two were quite normal in appearance. One of the no-whites, a female, was mated with male III.J. (p. 280).

For the mating of the one-sided no-white female see p. 340.

The male referred to above, with very thin white reticulation in the eye, was also mated with a normal red-eyed female. There were 47 black-eyed young, in 45 of these the white reticulation was very much reduced, varying from complete but very thin lines to a few scattered flecks of white, and in many cases more reduced in the eye of one side than in that of the other. In the other two of the 47 young ones the white was completely absent from the eyes of both sides. This result is unexpected because the reduction of the white pigment appears to be dominant over normal white pigment, whereas the absence of white pigment has in other cases always behaved as a recessive.

(2) Pair IV. The parents had normal black eyes, and gave 66 young, all normal. These young were left together for six months, and the vessel in which they were living then contained 28 survivors, three large

ones, 1 male and 2 females, and 25 young. The white pigment in the eyes of both the large females was very much reduced. Twenty-three of the young were black-eyed, half-grown animals, with normal extra-retinal pigment and 2 very small ones, just extruded, one of which had no-white eyes.

(3) A number of the animals brought in on February 11, 1915, were examined and all had normal eyes. They were kept together in one large bell jar, which was not examined until April 5, 1916. The bell-jar then contained 20 animals, all having black eyes with the white normal, excepting in one instance. This was a young animal and there was so little white pigment in the eyes that it required examination with the microscope (1 inch) to detect it.

For another instance of the independent origin of no-white eyes see p. 336.

SECTION IV. THE COLOURLESS EYE.

Cross between coloured No-white and Albino

(Plate VI).

The " albino " eye shows neither black nor red retinal pigment, and is irregular and imperfect in shape, the ommatidia being few in number and unequal in size. The " coloured no-white " eye lacks only the white extra-retinal pigment, the black or red pigment, as well as the shape of the eye, the number, the size, and the arrangement of the ommatidia being normal. When animals with eyes of these two kinds are mated together what is lacking in one is compensated by its presence in the other, and the offspring ought to be quite normal in appearance, since the three defects, lack of coloured pigment, lack of white pigment, and imperfect form are all recessives.

The theoretical analysis is as follows for the case of the albino carrying black and red crossed with a red no-white :—

If W represents the factor for the presence of white pigment and w that for its absence, the other letters being used as before :—

$$W\ W\ c\ c\ B\ R \times w\ w\ C\ C\ R\ R$$

Albino carrying	Black and Red	Red no-white
Male Gametes	W c B and W c R	
Female Gametes	w C R	
F_1 Zygotes	W w C c B R	W w C c R R
	Black with the white normal but carrying red, albino and no-white.	Red with the white normal carrying albino and no-white.

Similarly if we cross an albino carrying black with a red no-white, we should get all black-eyed offspring, the animals having the same constitution as the above, viz. black with the white normal, carrying red, albino and no-white.

If we cross an albino carrying red with a red no-white, we should get all red-eyed offspring with the white normal, but carrying albino and no-white.

For the next generation, if we mate together two of the black hybrids we should get :—

W w C c B R × W w C c B R

Black with the white normal, carrying red, albino and no-white. The gametes are (male and female being the same) :—

W C B, W C R, W c B, W c R, w C B, w C R, w c B, w c R

Zygotes :—

W C B W C B	W C R W C B	W c B W C B	W c R W C B	w C B W C B	w C R W C B	w c B W C B	w c R W C B
W C B W C R	W C R W C R	W c B W C R	W c R W C R	w C B W C R	w C R W C R	w c B W C R	w c R W C R
W C B W c B	W C R W c B	W c B W c B	W c R W c B	w C B W c B	w C R W c B	w c B W c B	w c R W c B
W C B W c R	W C R W c R	W c B W c R	W c R W c R	w C B W c R	w C R W c R	w c B W c R	w c R W c R
W C B w C B	W C R w C B	W c B w C B	W c R w C B	w C B w C B No-white	w C R w C B No-white	w c B w C B No-white	w c R w C B No-white
W C B w C R	W C R w C R	W c B w C R	W c R w C R	w C B w C R No-white	w C R w C R No-white	w c B w C R No-white	w c R w C R No-white
W C B w c B	W C R w c B	W c B w c B	W c R w c B	w C B w c B No-white	w C R w c B No-white	w c B w c B Albino No-white	w c R w c B Albino No-white
W C B w c R	W C R w c R	W c B w c R	W c R w c R	w C B w c R No-white	w C R w c R No-white	w c B w c R Albino No-white	w c R w c R Albino No-white

That is, out of every 64 animals there should be :—

16 "No-whites," of which 4 are Albino and therefore colourless	1 carrying Black
	1 ,, Red
	2 ,, Black and Red
9 are Black	1 Pure Black
	2 Black carrying Albino
	2 Black carrying Red
	4 Black carrying Red and Albino
3 are Red	1 Pure Red
	2 Red carrying Albino
48 with White, of which 27 are Black	1 Pure Black
	2 Black carrying Albino
	2 ,, ,, No-white
	4 ,, ,, Albino and No-white
	2 ,, ,, Red
	4 ,, ,, Red and Albino
	4 ,, ,, Red and No-white
	8 ,, ,, Red, Albino and No-white
9 are Red	1 Pure Red
	2 Red carrying Albino
	2 ,, ,, No-white
	4 ,, ,, Albino and No-white
12 are Albino	1 Albino carrying Black
	2 ,, ,, Black and No-white
	2 ,, ,, Black and Red
	4 ,, ,, Black, Red and No-white
	1 ,, ,, Red
	2 ,, ,, Red and No-white

This may be summarised as follows :—

27 Black-eyed, 9 Black no-white, 9 Red-eyed, 3 Red no-white, 12 Albino-eyed, 4 Albino no-white or Colourless.

From the above it will be seen that four of the no-whites out of each 64 offspring should be also albinos, that is to say, they should show neither white, black nor red pigment, and should therefore be quite colourless. At the time the analysis was made no animals having a quite colourless eye had been seen, and it was a great satisfaction to us to find that the first brood of grandchildren got by mating together two black-eyed children of the cross albino by red no-white, consisted of two normal black-eyed animals, one black no-white, and two quite colourless. Since then a number of others with colourless eyes have been bred. The full details of the experiments made may now be given.

Parent Generation.

1. *Albino carrying black and red mated with Red No-white* (**A**+B+R×**RN**).

A mating of this kind is illustrated on Plate III, Fig. 6, where the male (II.D.1.j.) is Albino and the female "No-white" (from Family K, Plate V). Eighty young were obtained of which 42 were normal black-eyed animals and 38 normal red-eyed.

Another mating of this kind gave 34 young, 17 normal black-eyed and 17 typical red-eyed young.

2. *Albino carrying black mated with Red No-white* (**A**+B×**RN**).

The male II.D.1.k. (Plate II) was mated with a female red "No-white" from Family VII (Plate V) and gave 38 young, all being normal black-eyed animals. (Two of these 38 young which were mated together gave in the first brood 1 colourless young one, which is referred to as C.27, p. 338.)

From several matings of this kind including the one mentioned a total of 158 young was obtained, all normal black-eyed animals. One of these matings is illustrated in Plate IV, Fig. 17 (cf. p. 349).

3. *Albino carrying red mated with Red No-white* (**A**+R×**RN**).

From the matings of this kind there resulted 137 young, all typical red-eyed animals.

*F.*1. *Generation from* **A**+B+R×**RN.**

Three typical experiments are illustrated on Plate VI, Figs. 1, 2 and 3, the ancestry of the animals used being shown on Plate III, Fig. 6.

Black with Black.

Fig. 1 (Plate VI) shows the result of mating together two black offspring (Plate III, Fig. 6, II.D.1.j.2.) of Albino carrying black and red crossed with Red No-white (see Parent generation above, Section I). The first five broods given in the figure consisted of 80 young.

The numbers of each category required by the theory (see p. 332) for 80 young are given below, and those actually obtained are placed beneath them:—

	Normal Blacks.	Black No-whites.	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-whites).
Theory	34	11	11	4	15	5
Experiment ..	38	11	10	3	14	4

Since the Plate was made further broods have been obtained from this pair and the figures now stand as follows, the total number of young being 417 :—

	Normal Blacks.	Black No-whites.	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-whites).
Theory	176	58	58	20	78	26
Experiment ..	185	57	54	27	75	19

In addition to the family illustrated in Fig. 1 (Plate VI) a number of other matings have been made of blacks carrying red belonging to Parent Generation 1 (**A**+B+R×**RN**). Adding together all the figures for the young obtained from these matings we have a total of 663 distributed as follows :-

	Normal Black.	Black No-white.	Normal Red.	Red No-white.	Normal Albino.	Albino No-White (or Colourless).
Theory	278	92	92	30	123	41
Experiment ..	278	93	89	50	118	35

Red with Red.

Fig. 2 (Plate VI) shows the result of mating together two red offspring (Plate III, Fig. 6, II.D.1.j.2.) of Albino carrying black and red crossed with Red No-white. See Parent Generation 1 (**A**+B+R×**RN**).

Theory requires that out of 16 animals, 12 should show white pigment, 9 of them being red and 3 albinos, and 4 should show no-white, 3 of them being red and 1 colourless.

Fig. 2 shows the first 5 broods with a total of 84 young, and the numbers of each category required by theory for this number are given below, with the numbers actually obtained beneath them.

	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-white).
Theory	47	16	16	5
Experiment	48	16	16	4

Since the plate was made further broods have been obtained and the total number of young is 141, distributed as follows :—

	Normal Reds.	Red No whites.	Normal Albinos.	Colourless (Albino No-white).
Theory	79	26	26	9
Experiment	79	26	24	12

In addition to the family illustrated in Fig. 2 (Plate VI) a number of other matings have been made of red with red belonging to this generation. Adding together all the figures for the young obtained from all the matings of this generation we have a total of 600 distributed as follows :—

	Normal Red.	Red No-white.	Normal Albino.	Colourless (Albino No-white).
Theory	338	112	112	38
Experiment	346	111	105	38

Black with Red.

Fig. 3 (Plate VI) shows the result of mating together a black and a red offspring (Plate III, Fig. 6, II.D.1.j.1.) of Albino carrying black and red crossed with Red No-white. See Parent Generation 1 (**A**+B+R × **RN**).

In this case theory requires that out of 32 young, 9 should be normal blacks, 9 normal reds, 3 black no-whites, 3 red no-whites, 6 normal albinos and 2 colourless (albino no-whites).

Fig. 3 shows the first 5 broods with a total of 100 young, the theoretical and experimental numbers for the categories being :—

	Normal Blacks.	Black No-whites.	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-whites).
Theory	28	9	28	9	18	6
Experiment ..	28	15	30	4	20	3

Since the plate was made further broods have been obtained, and the total number of young is 491, distributed as follows :—

	Normal Blacks.	Black No-whites.	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-whites).
Theory	138	46	138	46	92	30
Experiment ..	109	53	157	45	104	23

*F.*1. *Generation from* **A**+B×**RN.**

The young belonging to this generation were mated together and produced 434 young, classified as follows :—

	Normal Blacks.	Black No-whites.	Normal Reds.	Red No-whites.	Normal Albinos.	Colourless (Albino No-whites).
Theory	184	61	61	20	82	27
Experiment ..	164	60	66	27	94	23

*F.*1. *Generation from* **A**+R×**RN.**

The young belonging to this generation were mated together and produced 220 young, classified as follows :—

	Red.	Red No-white.	Albino.	Albino (Colourless) No-white.
Theory	124	41	41	14
Experiment	127	38	42	13

INDEPENDENT ORIGIN OF COLOURED NO-WHITE AND ALBINO NO-WHITE OR COLOURLESS EYES.

In the last section colourless-eyed animals were described amongst the grandchildren of the cross Albino eye by No-white eye, and it was shown that these were to be expected according to theory. These animals always had the eye colourless on both sides of the head.

Instances of colourless eyes have also occurred in two families amongst the offspring of our original Albino female mated with a pure Red male (**Cross** A) (Plate I).

(1) The Red-eyed male (I.F.) mated with the Red female (I.E.) had a very large number of young, 780 in twenty-six broods, 589 red eyes and 191 albinos (Plate I). Amongst the reds there was a small number of individuals in which the white extra-retinal pigment had become reduced or entirely disappeared, giving rise to the typical Red No-white eye. In 24 animals the white had almost but not entirely disappeared from one or both eyes, only a few small specks of white being discovered with a 1-inch power, four on right side, eight on left side, and twelve on both sides. In 14 animals the eye on one side had no white pigment (12 on the right side, 2 on the left), that on the other was normal. In 5 animals the white pigment had completely disappeared from both eyes, the eyes being typical Red No-whites.

A similar state of things occurred amongst the Albinos. In seven animals the white pigment had entirely disappeared from the eye of one side (5 on the left side and 2 on the right side), and was present as usual in the eye of the other side. In one animal the white pigment was absent from both eyes, which therefore were quite colourless (see pp. 286 and 339.2).

The following are the details of the No-whites in the successive broods:—

In Brood 1, one Red-eyed animal had the right eye affected, there being only a fleck or two of white; when mature the eye was completely no-white. It died without offspring. Another had very thin reticulation in both eyes. (Several of the next generation had hardly any white pigment in their eyes.)

In Brood 2, one Red-eyed animal had the right eye completely no-white.

In Brood 3, one Albino-eyed animal had the right eye small, and the left eye no-white, i.e. Colourless. (From the mating of two albinos of this Brood 3, 12 young were produced, one of which was Colourless on the right side, and one was Colourless on both sides. In the next generation again, 10 young were obtained from the mating of two of the normal albinos, and one of these again showed the no-white strain, having the right eye Colourless.)

In Brood 4, the animals were all normal-eyed. One Albino, a female, was mated with the Red male from Brood 1, which had very thin white reticulation in both eyes, and in their offspring the no-white strain appeared. (Out of 76 young produced by this pair 38 were Red-eyed, 29 with normal eyes, 3 with one eye normal and the other no-white, and 6 no-white on both sides ; 38 Albinos, 22 of which were normal-eyed and 16 no-white, i.e. Colourless. Two of these young albinos have mated, and had 41 young, 33 normal Albino-eyed and 8 Colourless, which is the usual 3 : 1 ratio. The Colourless have also had offspring, 8 all Colourless.)

In Brood 5, one Red-eyed had the right eye practically no-white, with only a fleck or two of white pigment, left eye normal. (Examined again at maturity the right eye was found to have developed the normal white reticulation, cf. p. 340.4.) One Albino had the left eye Colourless. (In the first brood of 13 young of the next generation one Red-eyed had the left eye no-white, and very little white pigment in the right eye.)

In Brood 6, one Red-eyed animal had the right eye no-white, and one Albino had the left eye Colourless. (In the next generation one Red had the left eye no-white, and very little white pigment in the right eye.)

In Broods 7 and 8, which were not examined for some days after extrusion, the animals were all normal-eyed.

In Brood 9 three Red-eyed animals were affected, one with the right eye, one with the left eye, and one with both eyes no-white ; and two Albinos, one having the right eye and one both eyes no-white.

In Brood 10, all the animals were normal-eyed.

In Brood 11, one Albino had the left eye no-white.

In Brood 12, two Reds had both eyes practically no-white.

In Brood 13, one Red had both eyes practically no-white.

In Brood 14, three Red-eyed were affected, two had the right eye and one had both eyes no-white.

A number of other Reds in Broods 10 to 14 showed a tendency for the white reticulation to break down.

In Brood 15 two Red-eyed had the right eye no-white, and one of the two had the reticulation much broken on the left side. Two others had the reticulation so much broken, one on the right and one on the left, as to be practically no-white, and in many others the reticulation was very thin. One Albino had the right eye affected, there being only one spot of the white pigment at the upper end of the eye.

In Brood 16, two of the Red-eyed had the left eye practically no-white.

In Brood 17, three Red-eyed were affected, one with the right eye, and two with the left practically no-white.

In Brood 18, one Red-eyed had the right eye no-white, and one Albino had the right eye no-white, and a very small eye on the left side.

In Brood 19, one Red-eyed was no-white on both sides.

In Brood 20, all the animals were normal-eyed.

In Brood 21, one Red-eyed had the right eye and one had the left eye no-white.

In Brood 22, two Red-eyed had hardly any white pigment in the eyes, and one Albino had the left eye Colourless.

In Brood 23 all the Red-eyed animals had the red pigment much reduced, giving a yellow appearance to the eyes, and two had the left eye practically no-white. This brood is breeding and has given so far, normal Reds, Red no-whites, one-sided Red no-whites and Albinos.

In Brood 24, the red pigment was greatly reduced, only 2 out of 19 Red-eyed showing a faint pink tinge, the others were of a pale yellow tint. Seven of them had hardly any white pigment, and in one of them the right eye was practically no-white. One Albino had the right eye very small.

In Brood 25, the coloured pigment in the Red-eyed animals was the normal bright red tint, one had very thin reticulation on the left side, one had the right eye no-white, and very thin reticulation in the left, one had the right eye no-white, with no red pigment in the centre of the eye, two had both eyes no-white.

The last Brood, 26, consisted of only three animals, Red-eyed, with the red pigment much reduced.

(2) The same Red-eyed male (I.F.) was mated with another Red-eyed female (I.G.) from the same brood as the last and had in 3 broods 46 red-eyed and 18 albino-eyed young (Plate I). The 3rd brood consisted of 25 red and 12 albino-eyed young. These were left together in one bowl, and 15 young were obtained from their chance matings, 4 red, 8 albino and 3 with colourless eyes on both sides.

Two of these colourless ones survived, a male and a female (Plate V, Fig. 5). For details of offspring, see p. 339.3.

Constitution of the Colourless Eye.

That these colourless eyes, whether obtained by breeding together no-whites and albinos (see p. 330) or having an independent origin, behave as recessives to white and to colour is shown by the following results :—

1. (a) A female with both eyes Colourless (C.27, see p. 333), belonging to the F_2 generation from the mating Albino carrying black crossed with Red No-white, was mated with an Albino male (Plate II, VI.B.2.t.) and produced 108 young in 5 broods all with the usual albino eyes.

Two of these broods have reached maturity and from their matings 218 young have been obtained, 168 with the usual albino eyes, and 50 albino no-whites. Theory demands for this number 164 albinos and 54 albino no-whites (Colourless).

Some of the albino-eyed young of this second generation have just become mature, and when mated together gave 19 albino-eyed and 5 albino-no-whites (Colourless).

(b) From another mating of this kind, Colourless female with Albino male, one brood of 18 young resulted, all with normal albino eyes. These mated together have given 106 young, 85 Albino-eyed and 21 Albino no-whites.

(c) The first F_3 brood from F_2 albinos (**A**+R+N×**A**+R+N) from the family described on p. 336 numbered 55, 45 usual-eyed albinos and 10 albino no-whites, i.e. Colourless. Theory requires 41 albinos and 14 Colourless.

2. A female with both eyes Colourless (**AN**+R) (Plate VII, Fig. 6) (whose parents are shown on Plate I, viz. I.E.3.l. ♂ and I.E.3.o. ♀, and whose ancestry is discussed on p. 336), the colourless character having originated independently, was mated with a Red No-white male **RN** descended from Family VII. The resulting broods are charted on Plate V, Fig. 4, there being 177 young, all with Red No-white eyes.

The offspring obtained by mating together individuals from the first brood of these young ones are shown on the plate. In the ten broods figured there were 124 young, 89 Red No-whites (=**RN**+AN) and 35 Colourless (**AN**+R). Altogether in this generation we have obtained

481 young, 359 Red No-whites and 122 Colourless. Theory requires
361 ,, ,, ,, 120 ,,

From the mating of the first two F_2 young which matured, a Red No-white male with a Colourless female, 24 young were obtained, **RN**+AN 14 and **AN**+R 10. The first mating from the next generation F_3 (**RN**+AN×**RN**+AN) produced 14 **RN**+AN and 3 **AN**+R.

3. Of the three Colourless-eyed young referred to on p. 338, which arose independently, two survived, a male and a female. These two mated together and the three first broods are shown on Plate V, Fig. 5. Altogether they produced 85 young, all Colourless (F_1). The first brood of these has reached maturity, and mated together these have produced 386 young all with colourless eyes (F_2). The first two of these broods are shown on the Plate. Some of these F_2 broods have just reached maturity, and in chance matings within the brood have produced 10 young, all Colourless (F_3).

SECTION V. ONE-SIDED NO-WHITES. ANIMALS WITH ONE EYE NORMAL AND THE OTHER ABNORMAL.

A number of instances have occurred in which the eye on one side of the head was normal, whilst that on the other was either a coloured "no-white" eye or a colourless eye, i.e. an albino "no-white."

In most cases these animals died before maturity, so that up to the present, we have never had males and females mature at the same time, to breed together.

We have therefore mated the few one-sided no-whites which survived with normal-eyed animals and with typical no-whites. The details of the experiments are as follows :—

1. Red female, *No-white on the Left side*, the white reticulation rather broken on the Right side, mated with a Red no-white male (Plate VI, Fig. 4).

This female is descended from the **B**+R+A female, VI.A.1.h. (p. 293), which was mated with a Red male from Pure Red Stock, and gave a brood of 7 young, 3 Black and 4 Red, hatched on May 18, 1916. On examining the brood, August 18, 1916, two Black females and three Red males were found with 25 young (6 Black and 17 Red), 23 of which were normal-eyed, and two, a Red and a Black (see 4), were no-white on the Left side.

The Red one was again examined on reaching maturity and the Left eye was found unchanged, still no-white. It was mated with a Red no-white male (i.e. one practically normal eye, to three no-white eyes), and produced 20 young, all with normal Red eyes (**R**+N).

These young were mated together and gave a total of 490, 365 Red-eyed, and 125 Red no-whites. In each animal both eyes were of the same type. The results therefore are in full agreement with the Mendelian theory of the dominance of the white pigment, the numbers required by the theory being 367 Red-eyed to 122 Red no-white.

2. A Black female from Pure Black stock (p. 329) *with the Left eye no-white*, and very little white reticulation in the Right eye, mated with a No-white male from the same stock and had 15 young, all with normal Black eyes.

3. An Albino female *with the Left eye no-white*, i.e. Colourless. Parentage, Albino male carrying Black (**A**+B) from Brood 1 of III.B (p. 279) and Red female IV.Y (p. 285). The female was mated with an Albino male, the eyes of which were very small and the shape of the head abnormal on both sides; 271 young were produced, all with the usual Albino eyes and head shape normal. From 3 pairs of these young mated within the brood 122 offspring were obtained, 121 being normal albinos and 1 being colourless on the left side and normal albino on the right, exactly resembling the grandmother.

4. It may be interesting to add here the account of the young Black female referred to in paragraph 1, above, and of the same parentage as the Red female described.

When hatched the Left eye was no-white, and the Right eye had only one streak of white in it. It was examined again at maturity and it was then found that the Right eye had developed the normal white reticulation, and the left eye had the upper half with the white reticulation, the lower half no-white. Mated with a Red no-white male, it had 64 offspring **B**+R+N 31 and **R**+N 33, all with normal eyes.

Two pairs of these have produced young; the first pair, Black with Red, had 83 young, 45 Black, 4 Black no-white, 24 Red, 10 Red no-white; and the second pair, Red (**R**+N) with Red (**R**+N), gave 53 young, 39 Red, 14 Red no-white, none showing any variation from the normal types.

These Red F_2 young are now mature, and their matings Red no-white by Red no-white have given 13 Red no-white, and Red (**R**+N) by Red no-white have produced 26 young, 11 Red and 15 Red no-white.

SUMMARY.

Sections I and II. Amongst the stock of *Gammarus chevreuxi* which had been kept under Laboratory conditions for at least two years a small number of animals appeared in which the coloured retinal pigment was absent, whilst the white extra-retinal pigment remained. The experiments described in the present paper have shown that these eyes were of two different kinds.

Eyes of the first kind were derived from a stock which originated in a cross between Black-eyed and Red-eyed animals, and were degenerate and irregular in shape. Four animals of this kind appeared in one brood, and such eyes have since been seen only in direct descendants from these. Eyes of this kind were found to behave as simple Mendelian recessives to eyes showing coloured retinal pigment, whether that pigment was red or black, and they are referred to in this paper as "albino" eyes.

Eyes of the second kind were derived from a pure red-eyed stock, and were perfect in shape. The absence of coloured pigment has been shown not to be inherited, and the one animal of the kind experimented with, when mated with a female of the first kind, gave all coloured offspring. By a study of the descendants of these coloured offspring it has been shown that the parent animal behaves in inheritance exactly as if it were one with normal red eyes.

In the course of this investigation all possible crosses have been made between Black-eyed, Red-eyed and Albino-eyed animals. In this way 4 different kinds of black-eyed animals were produced, viz. pure black, black carrying albino, black carrying red, and black carrying red and albino; 2 different kinds of red-eyed animals, viz. pure red and red carrying albino; 3 different kinds of albinos, viz. albino carrying black, albino carrying red, and albino carrying black and red.

The figures given below show the number of offspring obtained in our experiments by mating together animals of the constitutions specified in each heading. These are summary figures, giving the totals for all crosses of each particular kind, and include many cases which are not referred to in the previous sections of the paper. The figures demanded by theory are placed below those given by our experiments. The total number of animals of which both eyes were examined for eye-colour to Sept. 8th, 1917, is 26,553.

The figures are arranged in the following order under the different eye-colours :—

1. The matings giving offspring all of one colour ;
2. Those giving offspring of two colours in the proportion 3 : 1 ;
3. Those giving offspring of two colours, half of one and half of the other ;

4.–7. Those giving offspring of three colours.

1. *Matings giving normal-eyed*[*] *offspring all of one colour.*

Black, offspring all normal-eyed Black in appearance, in agreement with theory.

	Number of young, Black-eyed.	
B×**B**	275	
B×**B**+R	146	
B×**B**+A	87	
B×**B**+R+A	17	
B×**R**	618	
B×**R**+A	126	
B×**A**+B	18	
B×**A**+R	79	
B+R×**B**+A	46	
B+A×**R**	251	
B (half no-white)×**BN**	15	
BN×**B**+R+A	92	
A+B×**R**	87	
A+B×**RN**	158	Total, 2015.

Red, offspring all normal-eyed Red in appearance, in agreement with theory.

	Number of young, Red-eyed.	
R×**R**	1525	
R×**R**+A	679	
R×**A**+R	259	
R×**RN**	24	
RN×**A**+R	137	
R (half no-white)×**RN**	20	Total, 2644.

---

[*] In this section the word "normal-eyed" is used in the sense that the chalk-white extra-retinal pigment is present.

Albino, offspring all the usual-eyed Albino in appearance, in agreement with theory.

	Number of young, Albino-eyed.	
A+(?)×**A**+(?)	1157	
A+R×**A**+R	225	
A+R×**A**+(?)	330	
A+R×**A**+B+R	103	
A+R×**AN**	126	
A+(?)(half no-white)×**AN**	271	Total, 2212.

2. *Matings giving normal-eyed offspring of two colours in the proportion* 3 : 1.

		Number of young. Black-eyed.	Red-eyed.	
Black.				
B+R×**B**+R	Experiment	735	249	
	Theory	738	246	
B+R×**B**+R+A	Experiment	300	90	
	Theory	292	97	
B+R×**A**+B+R	Experiment	7	2	
	Theory	7	2	
B+R×**A**(?)	Experiment	13	7	
	Theory	15	5	Total, 1403.
		Black-eyed.	Albino-eyed.	
B+A×**B**+A	Experiment	468	156	
	Theory	468	156	
B+A×**B**+R+A	Experiment	144	59	
	Theory	153	51	
B+A×**R**+A	Experiment	481	158	
	Theory	480	160	Total, 1466.
Red.		Red-eyed.	Albino-eyed.	
R+A×**R**+A	Experiment	1408	471	
	Theory	1408	470	Total, 1879.

3. *Matings giving normal-eyed offspring of two colours in the proportion* 1 : 1.

		Number of young. Black-eyed.	Red-eyed.
Black.			
B+R×**R**	Experiment	403	410
	Theory	406	406
B+R×**R**+A	Experiment	44	48
	Theory	46	46
B+R×**RN**	Experiment	50	57
	Theory	53	53
B+R×**A**+R	Experiment	71	95
	Theory	83	83

		Number of young.		
Black.		Black-eyed.	Red-eyed.	
B+R+A×**R**	Experiment	180	165	
	Theory	172	172	
B+R+A×**RN**	Experiment	18	16	
	Theory	17	17	
A+B+R×**R**	Experiment	87	72	
	Theory	79	79	
A+B+R×**RN**	Experiment	31	31	
	Theory	31	31	Total, 1778.

		Black-eyed.	Albino-eyed.	
B+A×**A**+R	Experiment	103	106	
	Theory	104	104	
B+A×**A**+B+R	Experiment	5	16	
	Theory	10	10	
B+A×**A**+(?)	Experiment	24	25	
	Theory	24	25	
A+B×**B**+R+A	Experiment	8	6	
	Theory	7	7	
A+B×**R**+A	Experiment	76	77	
	Theory	76	77	Total, 446.

Red.		Red-eyed.	Albino-eyed.	
R+A×**A**+R	Experiment	601	554	
	Theory	577	577	Total, 1155.

4. *Matings giving normal-eyed offspring of three colours in the proportion* 9 : 3 : 4.

		Number of young.		
		Black-eyed.	Red-eyed.	Albino-eyed.
B+R+A×**B**+R+A	Experiment	542	189	241
	Theory	547	182	243

5. *Matings giving normal-eyed offspring of three colours in the proportion* 3 : 1 : 4.

B+R+A×**A**+B+R	Experiment	11	4	16
	Theory	12	4	15

6. *Matings giving normal-eyed offspring of three colours in the proportion* 1 : 1 : 2.

A+B+R×**R**+A	Experiment	84	92	147
	Theory	81	81	162
B+R+A×**A**+R	Experiment	31	8	34*
	Theory	18	18	26

* These totals are made up as follows :—

	Black.	Red.	Albino.
VI.A.1.d. ♂ × VI.B.2.u. ♀ . . .	1	3	20
VI.C.2.k. ♀ × VI.C.2.u. ♂ . . .	17	1	3
VI.C.3.e. ♀ × VI.B.2.t. ♂ . . .	13	4	11
	31	8	34

It will be seen that two of these families gave unexpected numbers.

7. *Matings giving normal-eyed offspring of three colours in the proportion* 3 : 3 : 2.

		Number of young.		
		Black-eyed.	Red-eyed.	Albino-eyed.
B+R+A×**R**+A	Experiment	235	169	144
	Theory	205	205	137

It will be noticed that in both this and the preceding instance the proportion of total coloured (red and black combined) to albino is in good agreement with the Mendelian theory. In each case, however, the experiment gives a great excess of blacks over reds, whereas theory requires equality in each case. The numbers are fairly large and it is possible that this result may have some significance.

Section III. Animals occurred in which the chalk-white extra-retinal pigment of the eyes was absent. These we have called "no-whites." This mutation appeared independently in several different stocks, and there is evidence that it may be produced in a series of steps or stages, the white pigment being gradually reduced in amount. In some cases the two eyes of the same animal differ in respect to the presence or absence of white pigment, or in the amount of white pigment. The "no-white" eye behaves in inheritance as a simple Mendelian recessive to the presence of white.

The following numbers are derived from the experiments made with these animals, including also the experiments made with the Albino no-whites (**AN**) or Colourless, described in the next Section.

1. *Matings giving no-white-eyed offspring all of one colour.*

Black, offspring all Black no-white in appearance, in agreement with theory.

	Number of young, Black no white.
BN×**BN**	13
BN×**RN**	13

Red, offspring all Red no-whites in appearance, in agreement with theory.

	Red no-whites.
RN×**RN**	61
RN×**AN**+R	177

Albino, offspring all Albino no-white in appearance, in agreement with theory.

	Albino no-whites (i.e. Colourless).
AN×**AN**	489

2. *Matings giving No-white offspring of 2 kinds in the proportion* 3 : 1.

		Number of young.	
		Red no-whites.	Albino no-whites.
RN+AN×**RN**+AN	Experiment	373	125
	Theory	373	125

3. *Matings giving No-white offspring of 2 kinds in the proportion* 1 : 1.

		Number of young.	
		Black no-whites.	Red no-whites.
BN+R×**RN**	Experiment	47	42
	Theory	44	44
		Red.	Albino.
RN+AN×**AN**+R	Experiment	14	10
	Theory	12	12

4. *Matings of normal-eyed animals carrying the factor for No-white*, the offspring of crosses between normal-eyed and no-whites.

(a) Those which give normal and no-white eyes of one colour in the proportion of 3 normal to 1 no-white, i.e. 3 : 1.

		Number of young.	
Black.		Black.	Black no-whites.
B+N×**B**+N	Experiment	24	7
	Theory	23	8
Red.		Red.	Red no-whites.
R+N×**R**+N	Experiment	440	149
	Theory	441	147
Albino.		Albino.	Albino no-whites.
A+R+N×**A**+R+N	Experiment	45	10
	Theory	41	14
A+N×**A**+N	Experiment	246	72
	Theory	238	79

(b) Those which give normal and no-white eyes in two colours in the proportions 9 : 3 : 3 : 1.

R+A+N×**R**+A+N	Normal Red.	Red No-white.	Normal Albino.	Colourless (Albino No-white).
Experiment	473	149	147	51
Theory	461	153	153	51

[**B**+R+N×**B**+R+N	Normal Red.	Black No-white.	Normal Red.	Red No-white.
Experiment	73	24	18	6
Theory	67	23	23	7

Note.—This is the K family VII, referred to on p. 326 in which the No-white mutation arose independently.]

(c) Those which give normal and no-white eyes in two colours in the proportions 3 : 1 : 3 : 1.

B+R+N×**R**+N	Normal Black.	Black No-white.	Normal Red.	Red No-white.
Experiment	45	4	24	10
Theory	31	10	31	10
B+R+A×**R**+N				
Experiment	7	3	3	1
Theory	6	2	6	2

(d) Those which give normal and no-white eyes in three colours in the proportions 9 : 3 : 9 : 3 : 6 : 2.

B+R+A+N ×**R**+A+N	Normal Black.	Black No-white.	Normal Red.	Red No-white.	Normal Albino.	Colourless (Albino No-white).
Experiment	109	53	157	45	104	23
Theory	138	46	138	46	92	30

(e) Those which give normal and no-white eyes in three colours in the proportion 27 : 9 : 9 : 3 : 12 : 4.

B+R+A+N× **B**+R+A+N	Normal Black.	Black No-white.	Normal Red.	Red No-white.	Normal Albino.	Colourless (Albino No-white).
Experiment	442	153	155	77	212	58
Theory	461	154	154	51	205	68

5. *Matings of animals, one normal-eyed carrying no-white, the other no-white.*

(a) Those which give normal and no-white eyes in one colour in the proportion 1 : 1.

		Normal Black.	Black No-white.
B+N×**BN**+R	Experiment	20	12
	Theory	16	16

		Normal Red.	Red No-white.
R+N×**RN**	Experiment	11	15
	Theory	13	13

(b) Those which give normal and no-white eyes in two colours in the proportions 3 : 3 : 1 : 1.

		Normal Black.	Black No-white.	Normal Red.	Red No-white.
B+R+N×**BN**+R	Experiment	26	21	3	10
	Theory	22·5	22·5	7·5	7·5

Section IV. By breeding together "albinos" and "no-whites" a certain proportion of offspring are produced in which both the coloured retinal pigment and the white extra-retinal pigment are absent. The eyes of these are quite colourless. The figures for these are given under Section III, Summary (pp. 346 and 347, b, d and e).

In addition to the colourless-eyed animals obtained by crossing albino- and no-whites, the colourless eye has arisen independently as a mutation.

Colourless-eyed animals mated together give all colourless-eyed offspring. The figures for these are given under Section III, Summary (p. 345. **AN**×**AN**).

GENERAL CONSIDERATIONS.

The phenomena described in the present paper show a progressive degeneration of the eye of Gammarus, taking place in a series of definite steps or stages, each of considerable magnitude. In the end we see the entire loss of the eye-pigment, together with a broken and irregular arrangement of the ommatidia and a great reduction in their number. We only need to imagine the continuation of this process for a few further steps, and we should reach the complete absence of eyes found in those blind genera of Amphipoda, which live in subterranean waters.

There is no direct proof that the change from the black eye-pigment of the wild animal to the red pigment, which occurred as a mutation in the eyes of the animals first used in the experiments, is due to the loss of a factor, but it seems not improbable that this may be the case. It is clear, at any rate, that these degenerative changes—the change from black pigment to red pigment, the entire loss of the coloured retinal pigment, the loss of the white extra-retinal pigment, and the degeneration in the form of the eye—all take place in exact conformity with Mendel's Law. The only feature which may at first sight seem to show a divergence from this law is the more gradual process of degeneration of the white extra-retinal pigment, which gives rise to what we call the "no-white" eyes described in Section III. This, however, may perhaps be capable of explanation by supposing that the loss of the pigment takes place in a series of steps, instead of in one single step.

The experiments recorded throw little or no light on the question of the conditions under which mutations arise or of the causes which give rise to mutations. The mutation of red eye-pigment has arisen once only in the whole course of the work and then after the animals had been kept under Laboratory conditions for only 2 generations.

The complete loss of the inter-retinal coloured pigment, giving rise to the "albino" eye, was first seen in one brood belonging to a particular family as described on p. 275, the female parent being from stock which had been living under laboratory conditions for over 3 years, and the male parent also from stock which had been in the laboratory for several generations. Out of 733 offspring of the same family, 4 with albino eyes occurred, all in one brood, two of which survived to produce offspring. All the animals used in the experiments were descendants of these two and the mutation has never occurred again.

The loss of the white, extra-retinal pigment, on the other hand, has originated apparently independently on several occasions. It is discussed in detail on p. 336. There seem to be some grounds for concluding that the loss of this pigment occurs when animals have been allowed to remain together for long periods and to interbreed promiscuously under somewhat unfavourable conditions as regards the quantity of water in which they are kept and the amount of food available. The loss of this pigment too, as already mentioned, seems sometimes to occur rather gradually and not suddenly as in the case of the change from black to red or the loss of the red.

Quite colourless eyes have arisen independently from albinos by the loss of the white extra-retinal pigment, just in the same way that no-white eyes have arisen from normal red and black eyes. Cases of this kind have been discussed on pp. 336–338.

A point of general interest which is somewhat strikingly illustrated by experiments described in this paper is the way in which the offspring of two abnormal, in this case degenerate, parents may themselves be quite normal in their characters, but are nevertheless capable of transmitting the abnormalities to their children. Such a case is that described on p. 333 (paragraph 2), where an Albino male (i.e. a male whose eye contained only the white extra-retinal pigment but neither black nor red inter-retinal pigment) was mated with a female Red No-white (i.e. one whose eyes contained only red inter-retinal pigment) with the result that all the young were black-eyed animals, normal in form and colour and indistinguishable on inspection from their wild ancestors (Plate VII, Figs. 4 and 5; Plate IV, Fig. 17). When, however, these or black-eyed animals of similar constitution are mated together the essential difference between them and the wild form comes out at once, all the abnormalities of the grandparents being reproduced in the grandchildren, and these abnormalities may even be combined in such a way that some of the grandchildren are more abnormal than the grandparents from whom they sprang. In the particular case mentioned the offspring consist, on the average, of 27 normal blacks, 9 black no-whites, 9 normal reds, 3 red no-whites, 12 normal albinos and 4 colourless (albino no-whites). (Cf. Plate VI, Fig. 1.)

Other results of a similar kind are recorded on p. 333 and the following pages.

EXPLANATION OF PLATES.

Plate I.

FIG. 1.—Explanation of the signs employed in the diagrams.

Normal Black, i.e. with both the black retinal and the white extra-retinal pigments present.

Black no-white, with the black retinal pigment present, the white pigment absent.

Red normal, with both the red retinal and the white extra-retinal pigments present.

Red no-white, with the red retinal pigment present, the white pigment absent.

Normal Albino, with the white pigment present, the coloured retinal pigment absent.

Albino no-white or *Colourless*, with both the coloured retinal and the white extra-retinal pigments absent.

A black spot attached outside the large circles indicates that the animal carries the factor for Black. Similarly, a red spot indicates that the factor for Red is carried, a small black circle the factor for Albino, and a small red circle the factor for No-white.

The small V-shaped sign outside the large circles means that it has not been determined whether the factor usually indicated in the position where the sign is placed is present or absent.

FIG. 2.—The matings of the Albino female A.C. (Albino carrying the factors for Black and Red) with a Red male and a Black male.

Cross A. (p. 275) with the male R.2 from Pure Red Stock.

One brood, I, and the young from their inter-matings.

Cross B. (p. 278) with the male K.A. Black carrying the factor for Red from Family K (p. 326 and Plate V).

Four broods, II, III, IV and V.

Many of the young died before reaching maturity. The constitution of those which survived to be tested is shown when known.

Plate II.

Cross C. The mating of the Albino female A.B. (Albino, carrying the factors for Black and Red), with the All-White male R.I.; the brood resulting from this mating is designated VI.

Cross B. The mating of the Albino female A.C. (from the same brood and of the same constitution as A.B.) with the male K.A. from the family K, shown on Plate V, Fig. 1, Black carrying the factor for Red; the brood from this mating is designated II. The number of the offspring resulting from the cross-mating of Brood VI, with Brood II, together with the sex, and constitution when known, of the surviving animals, are shown below. Animals to which no letter is attached could not be tested for constitution.

II.D 1, 2, 3, 4, are broods from the mating of two animals of Brood II. The number of young is shown, and the sex of those which reached maturity, but not the constitution, as, except in two or three instances, they were not tested for the factors carried.

Plate III.

FIG. 1.—*Mating of Albino with Albino;* offspring all Albino-eyed.

The male (h) and the female (l) are both from the second brood of II.D. (p. 279, Plate II).

FIG. 2.—*Mating of Albino carrying the factor for Black with Pure Red;* offspring all Black-eyed.

The male (**A**+B) is from the first brood of III.B. (p. 279, Plate I); the female (**R**) is VI.B.2.g. (p. 314, Plate II).

Fig. 3.—*Mating of Albino carrying the factor for Black with Red carrying the factor for Albino;* half the offspring Black-eyed, half Albino-eyed.

The male (**A**+B) is from the same brood as the male of Fig. 2 (pp. 279 and 286), the female (**R**+A) IV.Z. (p. 285, Plate I).

Fig. 4.—*Mating of Albino carrying the factor for Red with Pure Red;* offspring all Red-eyed.

The male (**R**) and the female (**A**+R) are both from a brood of the female I.G. of *Cross* A (p. 286).

Fig. 5.—*Mating of Albino carrying the factor for Red with Red carrying the factor for Albino;* half the offspring Red-eyed, and half Albino-eyed.

Both the male (**R**+A) and the female (**A**+R) are from the same brood as the pair of Fig. 4 (p. 286).

Fig. 6.—*Mating of Albino carrying the factors for Black and Red with Red No-white;* half the offspring, Black-eyed, carrying the factors for Red, Albino and No-white, and half Red-eyed, carrying the factors for Albino and No-white.

The male (**A**+B+R) is II.D.1.j. on Plate II (p. 333); the female is a Red no-white from Family K (Plate V, Fig. 1).

Some of this brood came to maturity, but died before their constitution could be proved; their sex is shown in the diagram, but no distinctive letters have been given them.

Plate IV.

Fig. 1.—*Mating of Black carrying the factors for Red and Albino with Pure Red;* half the offspring Black-eyed, half Red-eyed.

The female (**B**+R+A) (also in Figs. 2 and 3) is VI.A.1.l. (p. 293, Plate II); the male (**R**) came from the Pure Red Stock.

Fig. 2.—*Mating of Black carrying the factors for Red and Albino with Black carrying the factor for Red only;* offspring in the proportion of 3 Black-eyed to 1 Red-eyed.

Both animals from the one brood; the same female (**B**+R+A) as in Fig. 1 mated with the male (**B**+R) VI.A.1.a. (p. 291, Plate II).

Fig. 3.—*Mating of Black carrying the factors for Red and Albino with Red carrying the factor for Albino;* offspring should consist of Black-eyed, Red-eyed and Albino-eyed animals.

The same female (**B**+R+A) as in the two previous figures mated with the male (**R**+A) VI.C.1.o. (p. 310, Plate II).

Fig. 4.—*Mating of Black carrying the factor for Red only with Pure Red;* half the offspring Black-eyed, and half Red-eyed.

The same male (**B**+R) as in Fig. 2, mated with a female (**R**) from the Pure Red Stock.

Fig. 5.—*Mating of Black carrying the factor for Red only with Black carrying the factors for Red and Albino;* offspring in the proportion of 3 Black-eyed to 1 Red-eyed.

The same male (**B**+R) as in Figs. 2 and 4, mated with the female (**B**+R+A) VI.C.1.d. (p. 297, Plate II).

Fig. 6.—*Mating of Black carrying the factors for Red and Albino with Red carrying the factor for Albino;* offspring should consist of Black-eyed, Red-eyed and Albino-eyed animals.

Both animals from the one brood; the same female (**B**+R+A) as in Fig. 5; the male (**R**+A) as in Fig. 3.

Fig. 7.—*Mating of Pure Black with Pure Red;* offspring all Black-eyed.

The male (**B**) VI.A.1.c. (p. 292, Plate II); the female (**R**) from the Pure Red Stock.

FIG. 8.—*Mating of Pure Black with Red carrying the factor for Albino;* offspring all Black-eyed.

Both animals from the one brood; the same male (**B**) as in Fig. 7; the female (**R**+A) VI.A.1.q. (p. 309, Plate II).

FIG. 9.—*Mating of Red carrying the factor for Albino with Red carrying the factor for Albino;* offspring in the proportion of 3 Red-eyed to 1 Albino-eyed.

Both animals from the one brood; the male (**R**+A) VI.A.1.n. (p. 309, Plate II); the female (**R**+A) VI.A.1.q. (also in Figs. 8 and 10).

FIG. 10.—*Mating of Red carrying the factor for Albino with Pure Red;* offspring all Red-eyed.

Both animals from the one brood; the same female (**R**+A) as in Figs. 8 and 9; the male (**R**) VI.A.1.m. (p. 308, Plate II).

FIG. 11.—*Mating of Red carrying the factor for Albino with Pure Red;* offspring all Red-eyed.

Both animals from the one brood; the same male (**R**) as in Fig. 10; the female (**R**+A) VI.A.1.p. (p. 309, Plate II) (also in Fig. 12).

FIG. 12.—*Mating of Red carrying the factor for Albino with Red carrying the factor for Albino;* offspring in the proportion of 3 Red-eyed to 1 Albino-eyed.

The male (**R**+A) is II.B. (p. 284, Plate II); the female (**R**+A) VI.A.1.p. (also in Fig. 11).

FIG. 13.—*Mating of Black carrying the factor for Albino only with Pure Red;* offspring all Black-eyed.

The female (**B**+A) VI.C.1.k. (p. 298, Plate II); the male **R** from the Pure Red Stock.

FIG. 14.—*Mating of Black carrying the factors for Red and Albino with Black carrying the factor for Albino only;* offspring in the proportion of 3 Black-eyed to 1 Albino-eyed.

Both animals from the one brood; the male (**B**+R+A) VI.C.1.b. (p. 297, Plate II); the female (**B**+A) VI.C.1.k. was used in the previous figure.

FIG. 15.—*Mating of Black carrying the factors for Red and Albino with Black carrying the factors for Red and Albino;* offspring in the proportion of 9 Black-eyed to 3 Red-eyed to 4 Albino-eyed.

Both animals from the one brood; the male (**B**+R+A) was used in the previous figure; the female (**B**+R+A) VI.C.1.f. (p. 298, Plate II).

FIG. 16.—*Mating of Albino carrying the factor for Black only with Pure Red;* offspring all Black-eyed.

The male (**A**+B) VI.A.1.r. (p. 318, Plate II); the female (**R**) from the Pure Red Stock.

FIG. 17.—*Mating of Albino carrying the factor for Black only with Red No-white;* offspring all normal Black-eyed.

The same male (**A**+B) from the previous experiment—Fig. 16; the female (**RN**) VII.C.3.a. (p. 333) is an F_3 from the Family VII figured on Plate V.

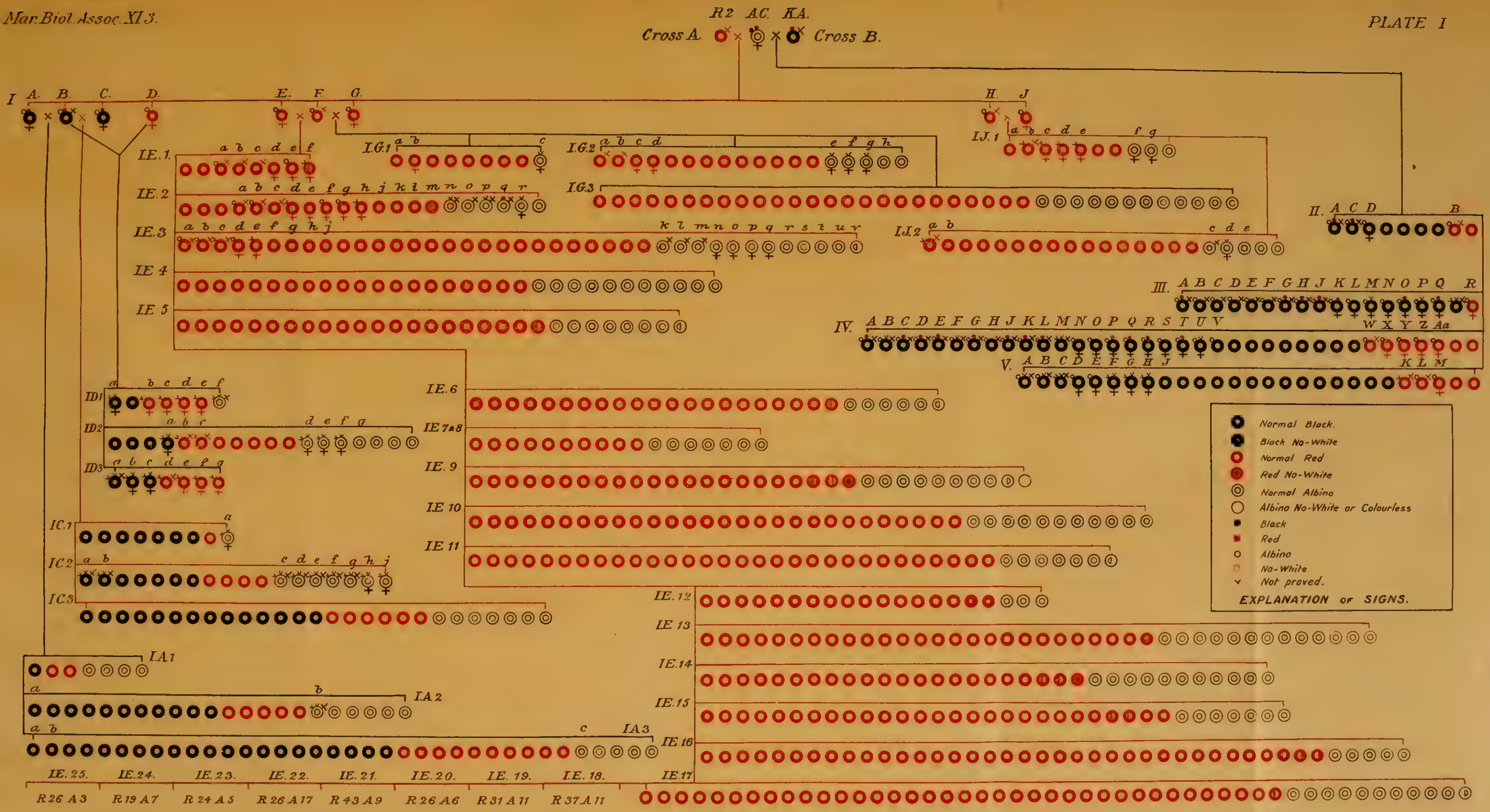
FIG. 18.—*Mating of Albino carrying the factor for Red only with Red carrying the factor for Albino;* half the offspring Red-eyed and half Albino-eyed.

Both animals from the one brood; the male (**R**+A) VI.B.2.a. (p. 313, Plate II); the female (**A**+R) VI.B.2.u. (p. 322, Plate II).

Plate V.

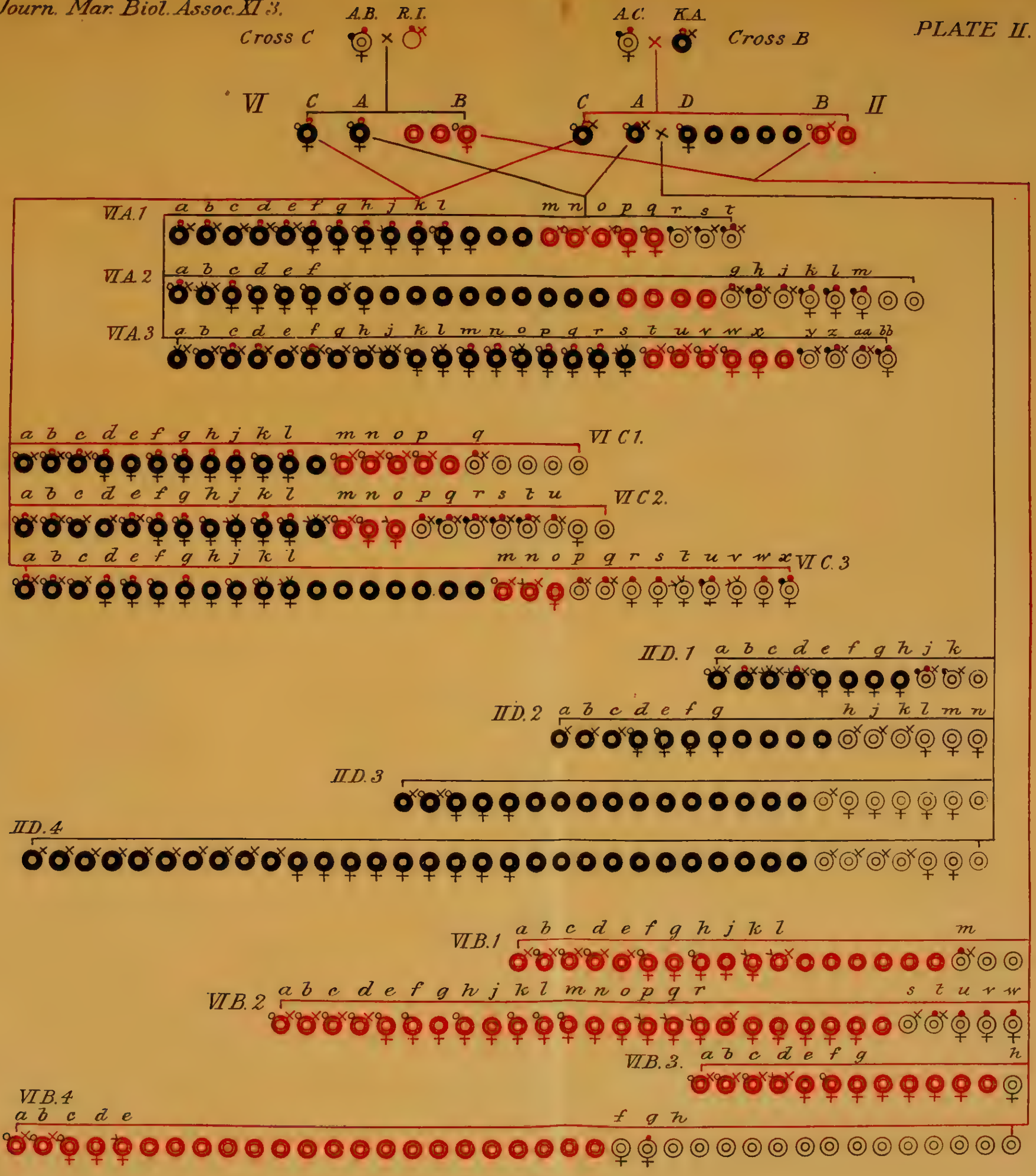
FIG. 1.—*The origin of K. Family, in which the No-White Mutation first occurred.*

Parent Generation, Pure Black mated with Pure Red. F_1 Generation, 24 survivors, all Black carrying the factor for Red. The No-whites appeared in some of the broods of the F_2 generation. One of these broods is figured here, with the offspring (F_3) resulting from the inter-mating in the brood; some of the F_4 generation are also shown.


R2 AC. KA.
Cross A.
Cross B.
I A. B. C. D. E. F. G. H. J
IE.1 a b c d e f
IE.2 a b c d e f g h j k l m n o p q r
IE.3 a b c d e f g h j k l m n o p q r s t u v
IE 4
IE 5
IG.1 a b c
IG.2 a b c d e f g h
IG.3
IJ.1 a b c d e f g
IJ.2 a b c d e
II. A C D B
III. A B C D E F G H J K L M N O P Q R
IV. A B C D E F G H J K L M N O P Q R S T U V W X Y Z Aa
V. A B C D E F G H J K L M
ID1 a b c d e f
ID2 a b c d e f g
ID3 a b c d e f g
IC.1 a
IC.2 a b c d e f g h j
IC3
IA1
IA 2 a b
IA3 a b c
IE.6
IE 7&8
IE. 9
IE 10
IE 11
IE.12
IE 13
IE.14
IE.15
IE.16
IE.17
IE. 25. IE.24. IE. 23. IE. 22. IE. 21. IE. 20. IE. 19. IE. 18.
R 26 A 3 R 19 A 7 R 24 A 5 R 26 A 17 R 43 A 9 R 26 A 6 R 31 A 11 R 37 A 11
Normal Black.
Black No-White
Normal Red
Red No-White
Normal Albino
Albino No-White or Colourless
Black
Red
Albino
No-White
Not proved.
EXPLANATION OF SIGNS.

E.J.A.
and
E.W.S.
del.

PLATE II.


A.B.
R.I.
Cross C
A.C.
K.A.
Cross B
VI
C
A
B
C
A
D
B
II
VI A.1
VI A.2
VI A.3
VI C 1.
VI C 2.
VI C. 3
II D. 1
II D. 2
II D. 3
II D. 4
VI B. 1
VI B. 2
VI B. 3.
VI B. 4

E.J.A. and E.W.S. del.

Fig. 1.

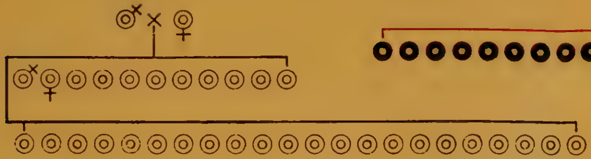


Fig. 2.

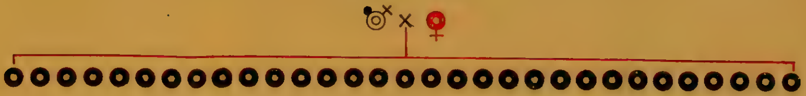


Fig. 3.

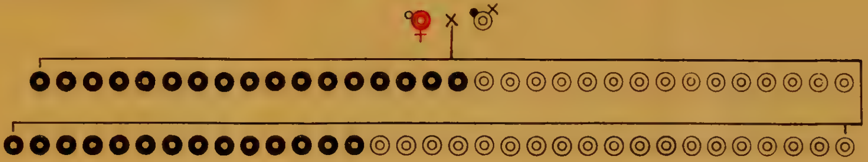


Fig. 5.

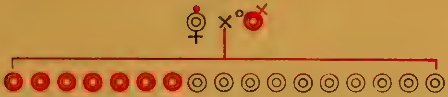


Fig. 6.

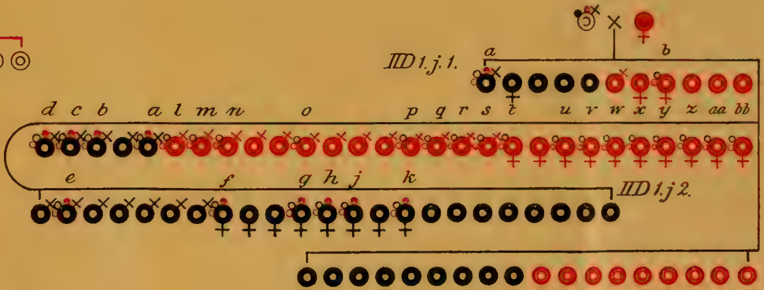
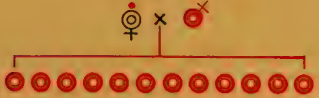

IID 1.j.1.
a
b
d c b a l m n o p q r s t u v w x y z aa bb
e f g h j k
IID 1.j 2.

Fig 4.



E.J.A. and E.W.S. del.

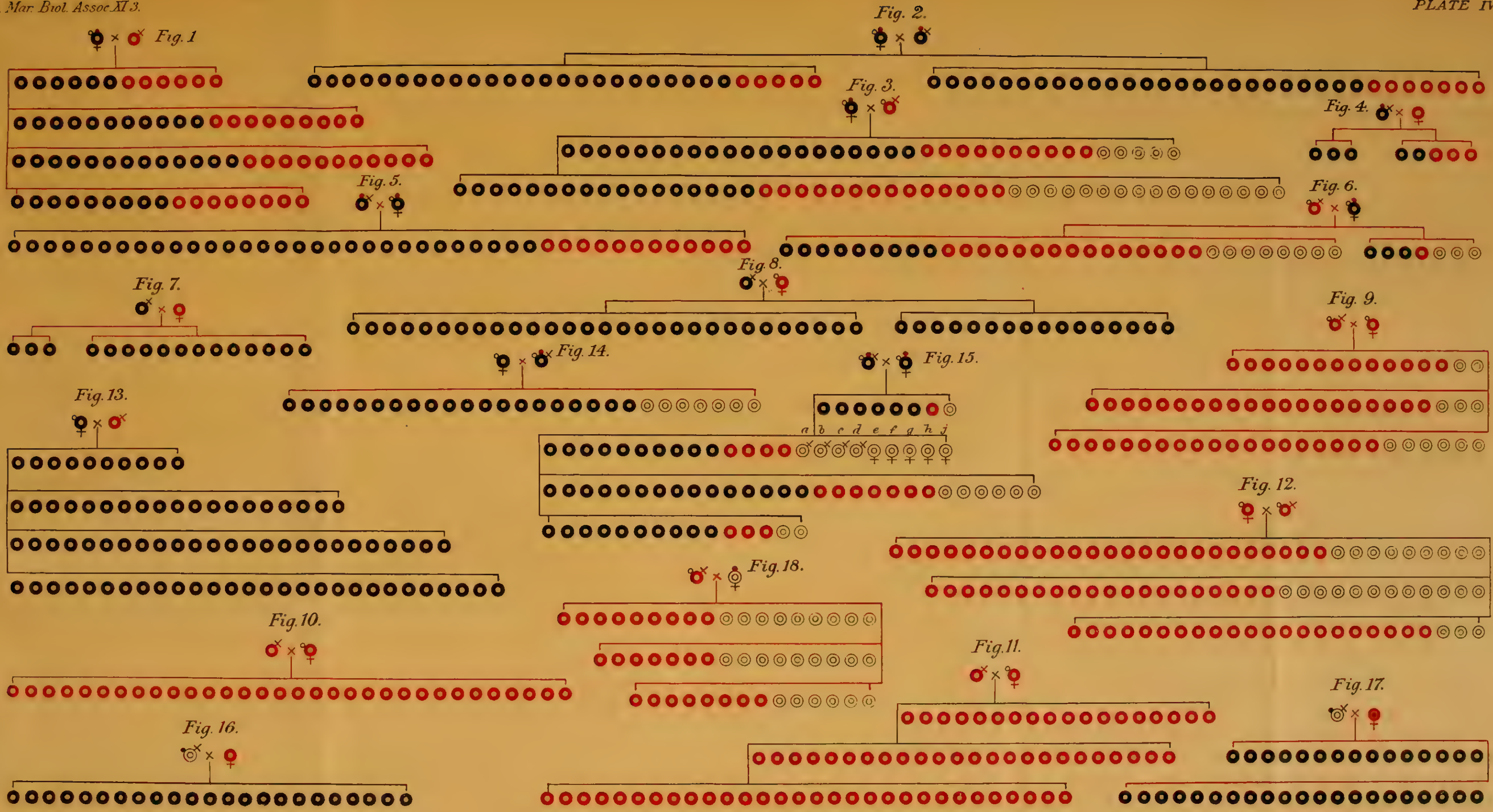


Fig. 1
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
a b c d e f g h j
Fig. 16.
Fig. 17.
Fig. 18.

E.J.A.
and
E.W.S.
del.

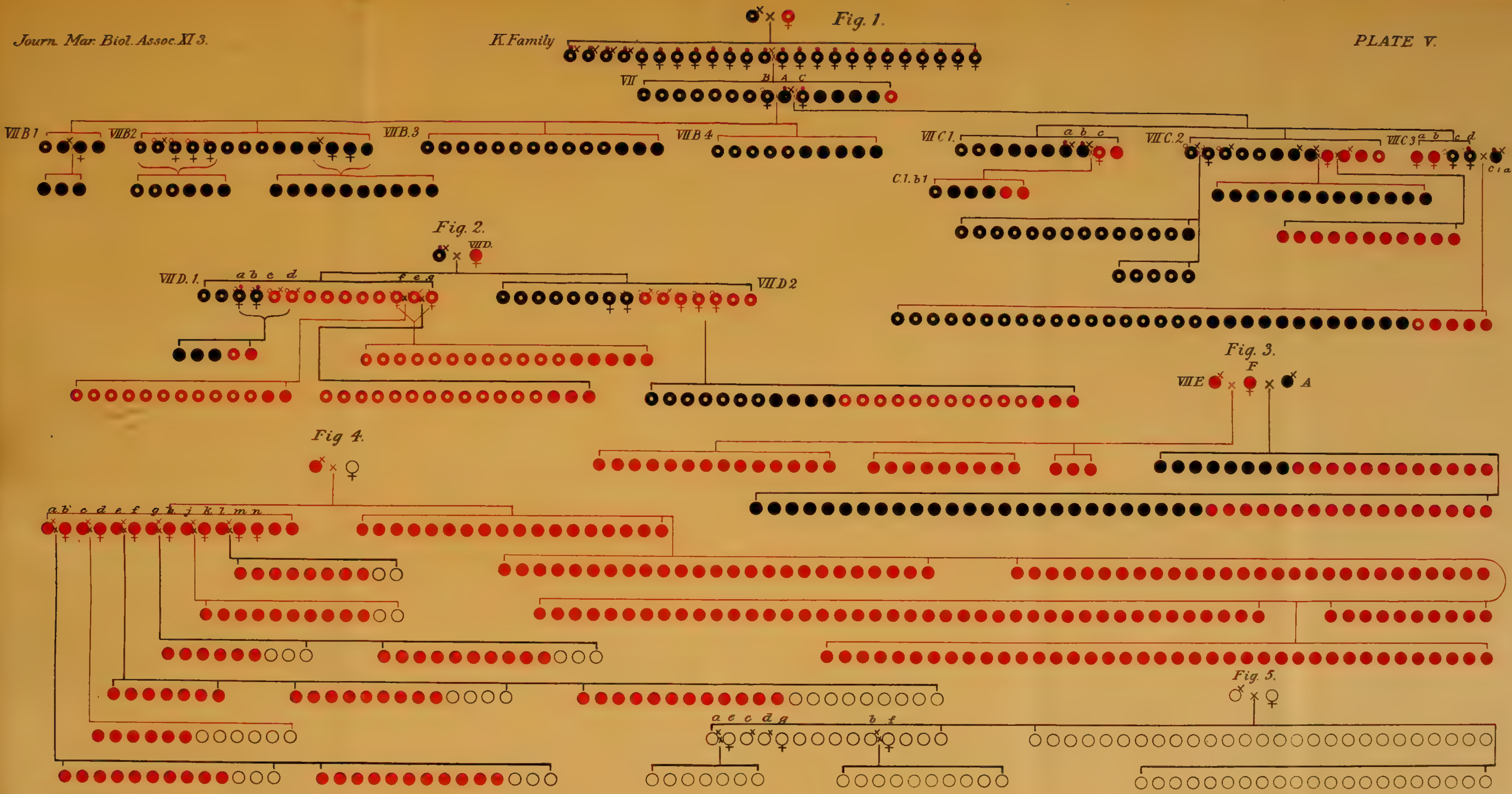


Fig. 1.
K Family
VII
B A C
VIIB1
VIIB2
VIIB.3
VIIB 4
VIIC1.
a b c
VIIC.2
VIIC3
a b c d
C1a
C.1.b1
Fig. 2.
VIID.
VIID.1.
a b c d
f e g
VIID2
Fig. 3.
VIIE
F
A
Fig 4.
a b c d e f g h j k l m n
Fig. 5.
a e c d g
b f

E.J.A. and E.W.S. del

PLATE VI.

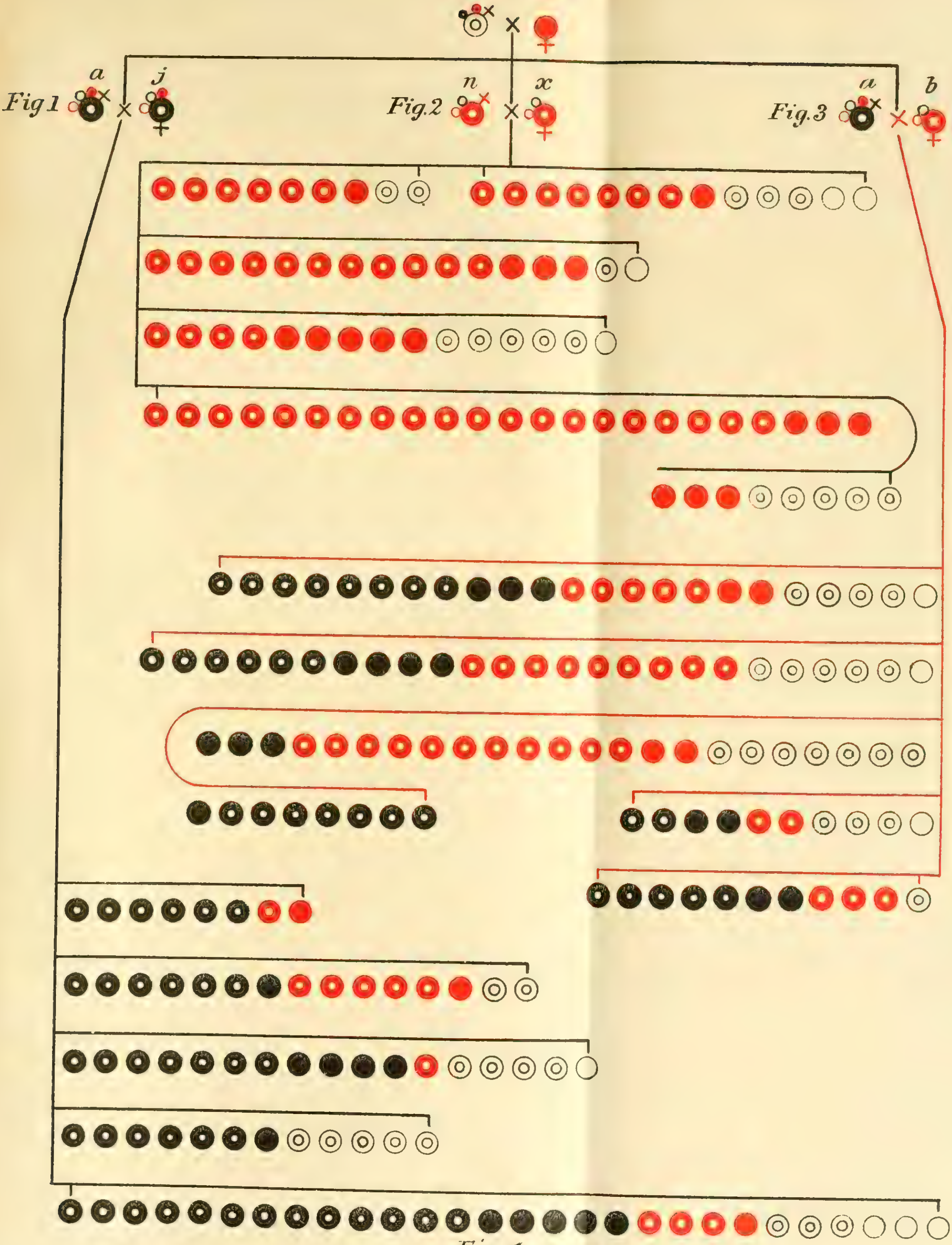
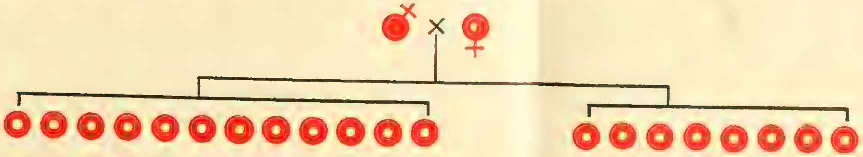


Fig 1

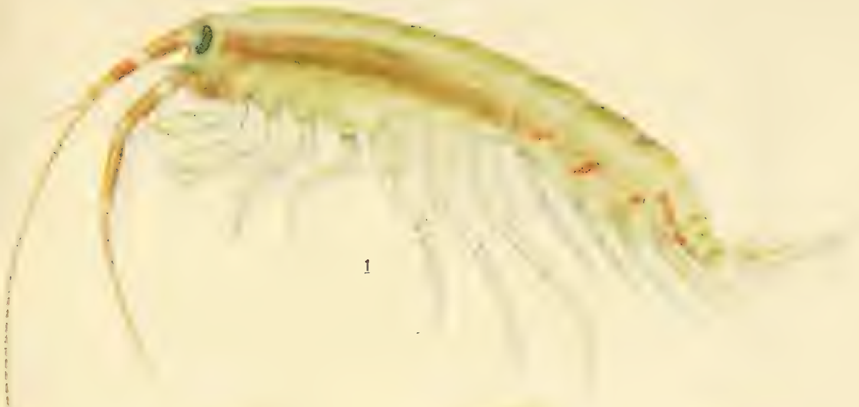
Fig. 2

Fig. 3

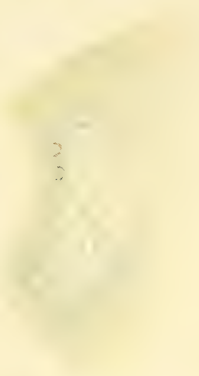
Fig. 4



E.J.A.
and
E.W.S.
del.



1

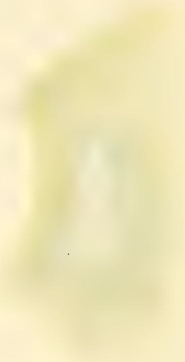


7

All-White.

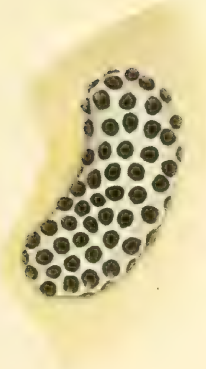
6

Colourless.



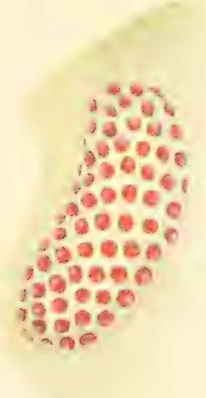
4

Normal Albino.



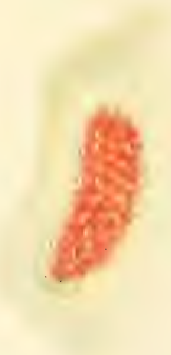
2

Normal Black.



3

Normal Red.



5

Red No-White.

E. W. Sexton del.

GAMMARUS CHEVREUXI.

As the young in this figure (and in Fig. 2) were not all examined immediately on extrusion, the proportions given of normal-eyed to no-white-eyed cannot be regarded as exact.

FIG. 2.—*Mating of a normal Black carrying the factor for Red with a Red No-white* female (VII.D) from a K Family brood not figured; with their F_1 and F_2 offspring (p. 326).

FIG. 3.—*Matings of Red and Black No-whites;* Red male (**RN**) VII.E; with Red female (**RN**) VII.F; the same Red female with Black male (**BN**+R) VII.A. of Fig. 1 (p. 328). VII.E. and VII.F. are from broods from K Family which are not figured.

FIG. 4.—*Mating of Red No-white with Albino No-white;* F_1 offspring all Red No-white; F_2 offspring in the proportion of 3 Red No-white to 1 Albino No-white. The figure shows the first ten F_2 broods from the inter-mating of the first F_1 brood. (See also p. 339.)

FIG. 5.—*Mating of Albino No-white or Colourless with Albino No-white;* offspring all Albino No-white.

For details of this mating, see pp. 338 and 339.

Plate VI.

Albino carrying the factors for Black and Red crossed with Red No-white (see also Plate III, Fig. 6, p. 333); the Black offspring carry the factors for Red, Albino and No-white; the Red offspring the factors for Albino and No-white.

FIG. 1.—Mating of two of the *Black* offspring from the second brood of the above cross; male a and female j (p. 333).

FIG. 2.—Mating of two of the *Red* offspring from the second brood; male n and female x (p. 334).

FIG. 3.—Mating of *Black and Red* offspring from the first brood of the above cross; male a and female b (p. 335).

FIG. 4.—*Mating of a Red half No-white with Red No-white;* all the offspring normal Red-eyed (p. 340).

The male is a red no-white descended from K Family.

The female is an F_2 from the first mating of VI.A.1.h. (**B**+R+A with **R**) (p. 293). Out of 25 young of the F_2 generation, two, a Red and a Black, were partly no-white when hatched. The Red one, figured here, had the Left eye no-white, the Right eye with the white reticulation present but thin; this did not alter throughout its life. The Black one, when hatched, had the Left eye no-white, and only one streak of white in the Right eye. Two months later, it reached maturity, a female, and it was then found the Right eye had developed the perfect white reticulation all over, and the Left eye had also developed it over the upper half of its surface.

Plate VII.

All the figures from living specimens.

FIG. 1.—*Gammarus chevreuxi* Sexton. Male. From a wild specimen. ×7.

FIG. 2.—Normal Black Eye. **B**. ×58.

FIG. 3.—Normal Red Eye. **R**. ×58.

FIG. 4.—Normal Albino Eye. **A**. from Female AB. (See p. 287.) Figured November 16th, 1915. ×58.

FIG. 5.—Red No-white. **RN**. ×58.

FIG. 6.—Colourless (Albino No-white. **AN**+R. See p. 339 for ancestry). ×58.

FIG. 7.—All-white perfect Eye. (See p. 287.) ×58.

Heredity in Plants, Animals, and Man.

Being the Presidential Address delivered before the Plymouth Institution, October 12th, 1916.

By

E. J. Allen, D.Sc., F.R.S.,
Director of the Plymouth Laboratory.

[Reprinted from the Transactions of the Plymouth Institution.]

With Diagrams 1–11 in the Text.

Of the many branches of biological enquiry which have occupied the attention of naturalists during the last twenty years the one which has perhaps yielded the most striking results, from a theoretical point of view, has been the study of heredity in plants and animals—the study of the laws according to which the characters of parents are transmitted to their descendants.

The practical achievements of the farmer, the gardener, and the animal breeder in obtaining and fixing innumerable varieties of cultivated plants and domesticated animals had made everyone familiar with the general facts that variations occur, and that these variations sometimes are and sometimes are not transmitted from parent to offspring. Common observation of the men, women, and children with whom we come in contact shows us that human beings also exhibit similar phenomena. Amongst a family of children several quite distinct types of feature, of build, of colour of hair or eye are found, and it is often quite plain from which parent, or from the family of which parent, a particular characteristic has been derived. The same thing is sometimes clearly true of mental and moral traits.

Charles Darwin, especially in his work "On the Variations of Animals and Plants under Domestication," brought together a great collection of facts bearing on this subject, which formed the basis upon which his theory of natural selection was built up. Around the question of the cause or origin of such variations much discussion has centred. Darwin himself was inclined to favour the view generally associated with the name of Lamarck, that variations were brought about by the direct action of the environment—of the conditions under which the life of the animal or plant was carried on—and that variations originating in this way were capable of being inherited. Changes of structure brought about by the use or disuse of organs were considered of particular importance in this connection. Especially when the environmental conditions had remained the same for many generations did the characters produced by them become, it was thought, permanently fixed in the species as part of its hereditary constitution. This view was strongly attacked by Weismann, who held that variations produced by external conditions, and especially by use and disuse of parts, were not hereditary, and the characters of the germ plasm as received from the parents were transmitted to the offspring without change. Weismann's view has been considered the more probable by the majority of biologists since he wrote, though by a minority it has always been subjected to vigorous criticism.

With the question of the causes that give rise to variations capable of being inherited, it is not however my intention to deal to-night. Accepting the fact, which cannot be disputed, that such variations do occur, and recognising that characters of the parent sometimes do and sometimes do not appear in the offspring, when parents with different characters are mated together, we shall consider the system or law in accordance with which the hereditary transmission of characters takes place.

What is now recognised as the epoch-making pioneer work in this subject was carried out by Gregor Mendel, Abbot of Brünn, a small town in Austria, and published by him in the Proceedings of the local natural history society at Brünn in 1865. This work unfortunately escaped attention for many years, and it was not until 1900 that the importance of Mendel's paper was recognised by de Vries, Correns and Tschermak, who all three about the same time brought it into notice. The work has since been repeated and extended by Bateson, Punnett and many other workers in this country, on the Continent, and in America, and to-day there is a very extensive literature dealing with heredity on Mendelian principles in plants, animals, and man.

Mendel chose the common garden pea for the purposes of his experiments, a plant which exists in a number of well-marked varieties, capable of being crossed easily one with the other. The nature of his experiments and the character of the results which he obtained will perhaps be made clear by the description of a simple example. There is one variety of the pea plant that produces seeds, which when the pods are fully ripe and dry are of a uniform yellow colour. Another variety, on the other hand, produces peas which when they are ripe and dry are green.

It will be well known to you that in order to produce a ripe seed, which shall be capable of germination and growth, the union is necessary of two elements which occur in the flower. These elements are the ovule, which lies at the base of the flower, and the pollen, which generally takes the form of a fine dust or powder, and is formed by the stamens. The pollen is the male element, the ovule the female element ; both are single cells, and together with the corresponding elements in animals they are called by the general name of *gametes*. The union of the ovule and pollen, which results in the formation of the ripe seed, is known as fertilisation. The general term applied to the ripe seed, the adult plant or the adult animal, which results from the union of the male and female gametes, is *zygote*—that which is yoked together. Two gametes or germ cells unite to form a zygote.

If plants of the variety which produces yellow peas are fertilised with the pollen from their own flowers or from flowers of the same variety, the seeds produced will all be yellow in colour, exactly resembling the parents. The variety breeds true to colour, and for however many generations the breeding is continued the colour remains the same, provided both parents in every case belong to the same variety.

Similarly the green-coloured variety, when the flowers are fertilised with their own pollen or with that from similar plants, produces pods which contain only green-coloured peas.

What Mendel did was to cross one of these varieties with the other. The ovules of a plant normally producing yellow-coloured peas were fertilised with pollen from a plant which produced green-coloured peas, or *vice versâ*. In this way a hybrid between the two varieties was obtained.

The hybrid peas resulting from this cross are all yellow in colour, and the result is the same whichever way the cross is made. The yellow colour is therefore said to be *dominant* to green, and green is said to be *recessive*.

This is illustrated in Diagram 1, in which the black discs represent yellow peas, the rings represent green peas.

The hybrid yellow seeds were then sown, and the resulting plants produced flowers. These flowers were allowed to fertilise themselves—that is to say, the ovules were fertilised with pollen from the same flower, so that hybrid was mated with hybrid. The pods produced by these plants were found to contain both yellow and green peas. The recessive form—the green—therefore, which was lost in the first hybrid generation, appears again in the second generation.

As the result of a large number of experiments Mendel found that the proportion of yellow to green seeds amongst the offspring of the hybrids was 3:1, there were three times as many yellow as green.

The seeds from this generation were collected and separately sown. The plants from the green seeds, when self-fertilised, produced all green seeds, and when these were again sown plants producing all green seeds again resulted. The pure recessive green variety had, therefore, completely segregated, or separated out from the hybrid, and the pure strain was completely recovered.

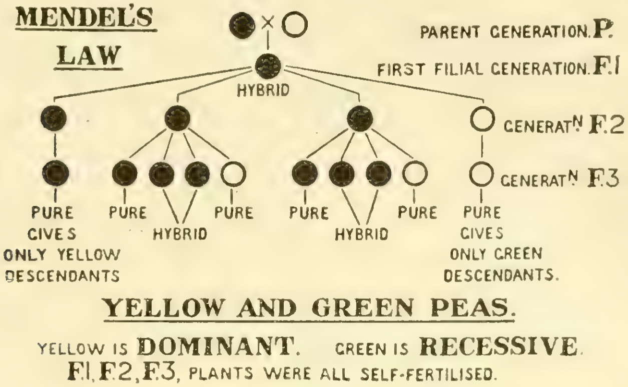

MENDEL'S LAW
PARENT GENERATION. P.
FIRST FILIAL GENERATION. F.1
HYBRID
GENERATN F.2
GENERATN F.3
PURE GIVES ONLY YELLOW DESCENDANTS
PURE
HYBRID
PURE
PURE
HYBRID
PURE
PURE GIVES ONLY GREEN DESCENDANTS.
YELLOW AND GREEN PEAS.
YELLOW IS DOMINANT. GREEN IS RECESSIVE.
F.1, F.2, F.3, PLANTS WERE ALL SELF-FERTILISED.

DIAGRAM 1.

The yellow seeds, on the other hand, behaved differently. Two kinds of plants were produced, one kind which on self-fertilisation gave all yellow seeds, the other kind which gave both green and yellow, the two colours being in the proportion of three yellow to one green. There were twice as many plants which gave both green and yellow seeds as there were plants which gave only yellow. Peas from the kind which produced only yellow peas, when sown, produced plants which again gave all yellows, and this continued in succeeding generations. The pure dominant yellow variety, like the green recessive, had completely separated out and was re-established.

What happens will be clear from the diagram.

The fact that one of a pair of characters is dominant and the other recessive is not, however, a primary or essential feature of the scheme of Mendelian inheritance. When one character is dominant the hybrid has the appearance of the parent which bore that character, but in other cases the hybrid appears quite different from either parent. This is well illustrated by the case of the Andalusian Fowl figured in Diagram 2. The Blue Andalusian is a variety well known to the poultry fancier. It was known that the strain was not pure, and that when bred together the birds gave not only blues, but also some blacks and some splashed whites—a white with splashes of dark colour on the feathers. After the rediscovery of Mendel's work this case was investigated by Bateson and Punnett, who found that the blue bird was really a hybrid between the black and the splashed white. Both the blacks and the splashed whites are pure strains ; blacks bred together give all blacks, whites bred together give all whites. When black is bred with white the birds obtained are all blue. The blue birds bred together give blacks, blues and splashed whites in the proportions of one black, two blues, one splashed white.

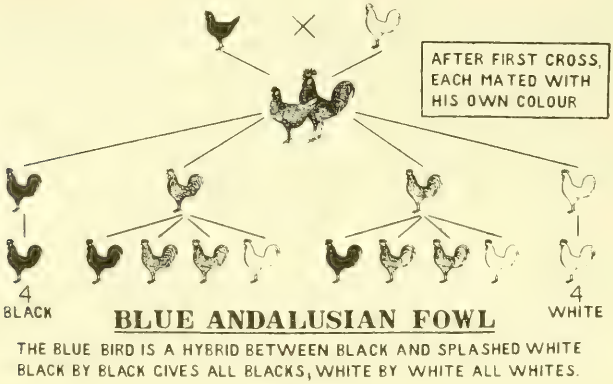

×
AFTER FIRST CROSS, EACH MATED WITH HIS OWN COLOUR
4 BLACK
BLUE ANDALUSIAN FOWL
4 WHITE
THE BLUE BIRD IS A HYBRID BETWEEN BLACK AND SPLASHED WHITE
BLACK BY BLACK GIVES ALL BLACKS, WHITE BY WHITE ALL WHITES.

Diagram 2.

When the blues of this second generation are bred together they give offspring in the same proportions : one black, two blues, one splashed white.

The diagram showing these relations should be compared with that representing the yellow and green peas. It will be seen that the scheme of inheritance is really exactly the same in the two cases, the apparent difference being due to the fact that whereas the hybrid pea takes on the character of the dominant yellow parent, the hybrid Andalusian has an appearance intermediate between the two parents.

That the yellow hybrid pea has a different constitution from its yellow parent, although its appearance is the same, is shown when hybrid plants are self-fertilised or bred together. As we have seen, the offspring are one pure yellow, two hybrid yellow, and one pure green. A further means of testing the hybrid character of this yellow pea is to fertilise the plant grown from it with pollen from a pure recessive plant grown from a green pea. Hybrid yellow crossed with green gives green and yellow peas in equal numbers.

Similarly a blue Andalusian mated with a splashed white gives blue hybrids and splashed whites in equal numbers, or a blue crossed with a black gives blues and blacks in equal numbers.

What I have described so far are the experimental facts, which have been repeatedly confirmed on these and many other plants and animals, and can be seen for himself by anyone who will take the trouble to carry out the necessary experimental work, taking all precautions to prevent false crossings by insects or false matings.

Mendel himself experimented also on a number of other characters in peas, and found that they followed the same scheme. Tall plants were dominant to dwarfs, and when the first tall hybrids were self-fertilised they gave tall and dwarf plants in the proportion of 3 : 1. Coloured flowers were dominant to white, but the whites reappeared again in the next generation.

In order to explain his results Mendel put forward a simple theory, the correctness of which all subsequent work has tended to confirm. Before attempting to explain this theory I must ask you to regard plants and animals from a point of view somewhat different from that which we usually take—from the point of view of the race or species rather than from that of the individual life. The plant withers, the flower fades, the creature dies, but still the race continues,

> "So careful of the type she seems,
> So careless of the single life."

How is this continuity of the race preserved ? That is the fundamental question which the physiology of heredity must seek to answer. What we know is that the germ cell, the germ plasm as Weismann called it, passes on uninterruptedly from generation to generation, increasing in bulk by the absorption of nourishment, dividing and subdividing, but apparently only seldom or extremely slowly undergoing any essential modification of its structure. The permanent, essential feature for the species is this germ plasm ; the body of the individual plant or animal is an elaborate but purely temporary home for its protection and nourishment. As Samuel Butler puts it in his quaint way " a hen is merely an egg's way of producing another egg." " The germ plasm, according to this view," says Darbishire " is immortal ; the excrescence, the body, is mortal."

It is in the gametes or germ cells—the ovule and the pollen of the plant and the corresponding structures of the animal—that the germ plasm is carried on. In the higher plants and animals this transmission is generally, though not always, complicated by the introduction of the phenomenon of sex, the union of the germ cells from two individuals of the species, or at least of germ cells of two different kinds.

In formulating his theory to account for the scheme of the hereditary transmission of characters which has been described, Mendel directed his attention primarily to the germ cells. Every gamete, that is to say every ovule and every grain of pollen, must contain something by means of which each character of the offspring is determined. What this something is, whether a material particle, a definite chemical substance, or some special arrangement of the molecules, we have no idea. For want of a better name it is usual to call it a "factor." Thus we should say that each ovule and each pollen grain of the green pea contains a "factor" for green colour ; each ovule and each pollen grain of the pure yellow pea contains a "factor" for yellow colour. When he had to deal with two alternative characters in a plant, such as green and yellow colour, Mendel assumed that any particular gamete was able to contain the factor for only one of these characters. In the same gamete the two characters are mutually exclusive. Each gamete *must* be pure for one or other of the factors. In the zygote, the individual produced by the union of two gametes, on the other hand, the factors for the two characters can both have place.

Let us see how this conception can be applied to the case of the yellow and green peas. In Diagram 3 the factor for yellow colour is represented

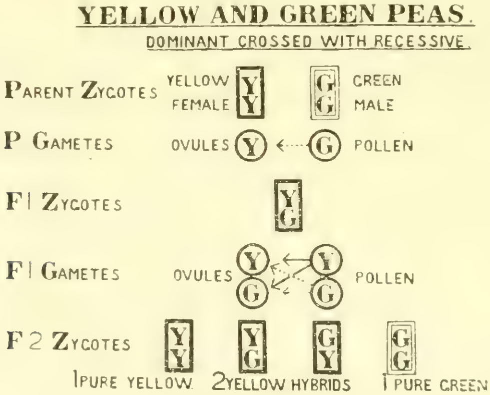

YELLOW AND GREEN PEAS.
DOMINANT CROSSED WITH RECESSIVE.
PARENT ZYGOTES
YELLOW FEMALE
Y
Y
G
G
GREEN MALE
P GAMETES
OVULES
Y
G
POLLEN
F1 ZYGOTES
Y
G
F1 GAMETES
OVULES
Y
G
Y
G
POLLEN
F2 ZYGOTES
Y
Y
Y
G
G
Y
G
G
1 PURE YELLOW
2 YELLOW HYBRIDS
1 PURE GREEN

DIAGRAM 3.

by **Y**, that for green colour by **G**. The pure yellow peas never produce anything but yellow ; we may therefore represent their constitution by $\boxed{\begin{matrix}Y\\Y\end{matrix}}$, one factor having been derived from each parent. Similarly, pure green will be $\boxed{\begin{matrix}G\\G\end{matrix}}$. These will produce gametes

Y male, **Y** female, in the one case,
G male, **G** female, in the other, and no other kinds are possible.

If we cross the two, the only possible combination is $\boxed{\begin{matrix}Y\\G\end{matrix}}$, which will represent the constitution of the 1st Hybrid generation. What Mendel's theory lays down is that when gametes are formed by these hybrids with the constitution $\boxed{\begin{matrix}Y\\G\end{matrix}}$, only one of the factors can enter into the same gamete, so that we have gametes of two kinds, the first containing the **Y** factor only, the second containing the **G** factor only.

If the gametes from a male and a female individual of these hybrids are now allowed to unite together they can do so in four different ways, and in four ways only. Amongst a large number coming together by chance equal numbers of each combination will result.

The combinations are :-

Y male with **Y** female, gives $\boxed{\begin{matrix}Y\\Y\end{matrix}}$ original pure yellow pea.
Y ,, ,, **G** ,, ,, $\boxed{\begin{matrix}Y\\G\end{matrix}}$ yellow pea, because yellow is dominant to green, but hybrid in constitution.
G .. .. **Y** ,, ,, $\boxed{\begin{matrix}G\\Y\end{matrix}}$ ditto.
G .. .. **G** ,, ,, $\boxed{\begin{matrix}G\\G\end{matrix}}$ original pure green pea.

We have therefore in the second hybrid generation (F.2.)

	1 Y Y	**2 Y G**	**1 G G**
that is	1 pure yellow,	2 hybrid yellow,	1 pure green.

This result agrees exactly with the facts as determined by experiment. Mendel's theory of the purity of the gametes is, therefore, in this case in complete accord with the facts.

We may test it further by seeing the result of crossing a hybrid yellow pea with a pure green pea, as illustrated in Diagram 4.

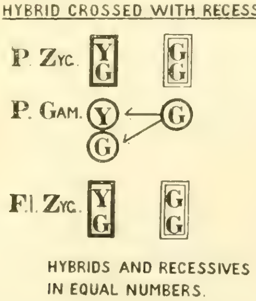


DIAGRAM 4.

The hybrid yellow contains the factors for both yellow and green, its constitution being $\boxed{\begin{matrix}Y\\G\end{matrix}}$, and it produces gametes **Y** and **G** in equal numbers.

The constitution of the green pea is $\left\|\begin{matrix}\mathbf{G}\\ \mathbf{G}\end{matrix}\right\|$, and it produces gametes of one kind only, namely **G**. If we unite equal numbers of **Y** and **G** with **G** only, we get equal numbers of $\boxed{\begin{matrix}\mathbf{Y}\\ \mathbf{G}\end{matrix}}$ and $\begin{matrix}\mathbf{G}\\ \mathbf{G}\end{matrix}$, that is equal numbers of the yellow hybrid and of the pure green. This result is again in accordance with experiment.

So far we have considered in each case only one pair of alternative characters. There are of course often a number of such pairs existing at the same time, each pair of which behaves in accordance with Mendel's law. This gives us a result which perhaps appears at first sight to be more complex than it really is. Diagram 5 (p. 364) represents a case studied by Mendel in peas, in which two pairs of characters are involved. First we have the two colours, yellow and green, which have already been considered. At the same time, some of the peas are round in shape, whilst others are very much wrinkled, the wrinkling being really dependent upon the character of the starch grains which constitute the bulk of the pea. In the diagram yellow is represented by a broad black line, green by a broad white line, wrinkled by a broken line.

If we cross-fertilise flowers from a plant bearing pure yellow, wrinkled peas with those of one bearing green round ones, we get in the first hybrid generation yellow round peas. Yellow is dominant to green, as we already know, and round is dominant to wrinkled, which is recessive.

Plants grown from such double hybrid peas were allowed to self-fertilise and four kinds of peas were produced: yellow round, yellow wrinkled, green round, and green wrinkled. Mendel's figures for this cross are shown below, the figures required by theory being placed underneath them:

	Yellow round.	Yellow wrinkled.	Green round.	Green wrinkled.
Mendel's Experiment .	315	101	108	32
Theory	313	104	104	35
	9 :	3 :	3 :	1

The combination which contained two dominants, yellow and round, was most numerously represented, that containing two recessives, green and wrinkled, was least numerous.

The theoretical analysis of the case is as follows:—

Let **Y**=yellow, **G**=green, **R**=round, **W**=wrinkled.

The constitution of the original parents will be

$$\boxed{\begin{matrix}\mathrm{Y\ W}\\ \mathrm{Y\ W}\end{matrix}}\qquad\qquad\begin{matrix}\mathrm{G\ R}\\ \mathrm{G\ R}\end{matrix}$$

Yellow wrinkled.	Green round.

Gametes :— **Y W.** **G R.**

The Hybrid must therefore be $\boxed{\begin{matrix}\mathrm{Y\ W}\\ \mathrm{G\ R}\end{matrix}}$

The Gametes from this hybrid are :—

Females . .	**Y W,**	**Y R,**	**G R,**	**G W.**
Males . .	**Y W,**	**Y R,**	**G R,**	**G W.**

The second (F.2.) generation will therefore give (see Diagram 5) :—

Y W **Y W** Yellow wrinkled.	**Y R** **Y W** Yellow round.	**G R** **Y W** Yellow round.	**G W** **Y W** Yellow wrinkled.
Y W **Y R** Yellow round.	**Y R** **Y R** Yellow round.	**G R** **Y R** Yellow round.	**G W** **Y R** Yellow round.
Y W **G R** Yellow round.	**Y R** **G R** Yellow round.	**G R** **G R** Green round.	**G W** **G R** Green round.
Y W **G W** Yellow wrinkled.	**Y R** **G W** Yellow round.	**G R** **G W** Green round.	**G W** **G W** Green wrinkled.

That is 9 Yellow round, 3 Yellow wrinkled.
3 Green round, 1 Green wrinkled.

It will be seen by an examination of Diagram 5 that the yellow rounds of the second hybrid generation have not all the same constitution. Some of them carry a factor for green, which being recessive does not appear in the visible result of the experiment ; some carry a factor for wrinkled, which also is recessive. That these factors are actually present can be proved by continuing the experiment to the next generation. Similarly the yellow wrinkled and the green rounds are not all the same.

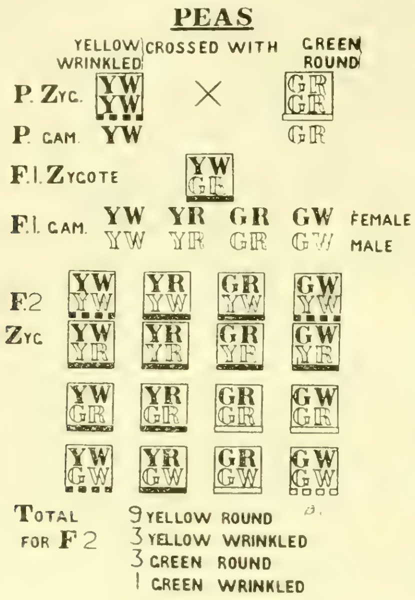

PEAS
YELLOW WRINKLED
CROSSED WITH
GREEN ROUND
P. ZYC.
YW YW
×
GR GR
P. GAM.
YW
GR
F.1. ZYGOTE
YW GR
F.1. GAM.
YW YR GR GW FEMALE
YW YR GR GW MALE
F2 ZYC
YW YW
YR YW
GR YW
GW YW
YW YR
YR YR
GR YR
GW YR
YW GR
YR GR
GR GR
GW GR
YW GW
YR GW
GR GW
GW GW
TOTAL FOR F2
9 YELLOW ROUND
3 YELLOW WRINKLED
3 GREEN ROUND
1 GREEN WRINKLED

DIAGRAM 5.

In the case of the green wrinkled, on the other hand—the double recessive—one constitution only occurs, and these peas would all breed true for however many generations the breeding were continued.

From what has been said already you will I hope have got a clear idea of the simple law, first enunciated by Mendel, which often governs the hereditary transmission of characters from parent to offspring. I propose now to communicate to you some results of the study of a particular instance of Mendelian inheritance, which has been worked out during the last two or three years in connection with the Marine Biological Laboratory. One paper, describing the earlier portions of the work, has been published already in the Journal of the Marine Biological Association, bearing the title "Experiments on the Mendelian Inheritance of Eye-colour in the Amphipod *Gammarus chevreuxi*, by E. W. Sexton and M. B. Wing." I have now in preparation a further paper (see page 273 of this Journal) dealing with the later investigations, the experimental work connected with which has been carried out by Mrs. Sexton.*

SEXTON, E. W., and WING, M. B. Experiments on the Mendelian Inheritance of Eye-colour in the Amphipod *Gammarus chevreuxi*. Journ. Mar. Biol. Assoc., XI, p. 18. 1916.

ALLEN, E. J., and SEXTON, E. W. The Loss of the Eye-pigment in *Gammarus chevreuxi*. Journ. Mar. Biol. Assoc., XI, p. 273. 1917.

Gammarus chevreuxi is a small shrimp-like animal, belonging to the Crustacean order, Amphipoda. It is about ½ inch long, and lives in great abundance in the brackish-water ditches at Chelson Meadow, just above Laira Bridge. It has never been found anywhere else. A drawing of the animal is shown on Plate VII, Fig. 1, which accompanies the preceding paper by Allen and Sexton in this number of the Journal.

The animals are kept alive easily in glass finger-bowls and feed freely on dead leaves, especially on elm leaves. The eggs are carried by the female in a brood pouch until they are hatched. As soon as one batch of eggs is hatched and the young liberated from the pouch, another batch is laid. A batch may contain as many as 50 eggs, so that a large number of young can be obtained altogether from one pair of animals. The eggs take 14 days to hatch at a temperature of about 60° F. The young grow rapidly and reach maturity in about 36 days at summer temperatures. Hence from 5 to 6 generations can be obtained in the course of a year, a fact which makes the animal specially suitable for the study of the problems of heredity.

The eye of *Gammarus*, like that of all crustaceans and insects, is of the compound type. It is made up of a considerable number of single elements, the ommatidia, each provided with a simple lens and receiving a nerve-fibre from the optic nerve.

In the normal animal each ommatidium is surrounded by 5 pigment cells, which lie deeply in the tissue of the eye, and are filled with pigment of a jet-black colour. Just below the surface of the cuticle or skin and surrounding the black pigment there is a quantity of milk-white or rather chalk-white pigment. This gives the whole eye, when looked at directly in the living animal, a honeycombed appearance, the white pigment forming a kind of network in which the round, black ommatidia are enmeshed. (See Plate VII, Fig. 2, of preceding paper.)

Whilst the habits and development of this animal were being studied, there appeared amongst the descendants of a pair of normal black-eyed *Gammarus* brought in from Chelson Meadow in June, 1912, in the third generation, that is amongst the grandchildren, a small number of young ones which had bright red eyes. The usual black pigment was replaced by red pigment, the network of chalk-white remaining as in the ordinary eyes. (Plate VII, Fig. 3, of preceding paper.) From this family a race of red-eyed animals was established, which has been used in these experiments. It is only in this one family that red eyes have ever appeared, and although very many thousands of specimens from the natural habitat have been examined, and many thousands more have been bred from pure black-eyed parents, no other case of the sudden appearance of a red eye has been met with.

Sudden and unexpected changes in a character of a pure race have been known by naturalists, as well as by practical breeders, to occur from time to time in both animals and plants, and are called in popular language "sports." Sometimes, no doubt, these sports are due to the reappearance of a latent or hidden character, which existed in the ancestry of the organism; at other times the so-called sports may be due to a sudden change in the constitution of the individual or of the germ cell from which it sprang, so that the character may be said to originate in the particular individual, instead of being inherited from its ancestors. To new characters which originate suddenly in this way the name mutation has been given. The red eye of *Gammarus* may be described as a mutation, appearing in the third generation of a wild animal which had been subjected to the artificial conditions of captivity.

The red-eye is transmitted from parent to offspring, and it behaves quite in a typical Mendelian way, red eye-colour being recessive (like the green pea), and black eye-colour dominant (like the yellow pea). For use in the hybridisation experiments a pure black stock, obtained from Chelson, was kept and thoroughly tested. The stock was maintained for over three years, the offspring and descendants being all examined at different seasons of the year, and in no single case has one with red eyes been found amongst them. Numbers of pairs of red-eyed animals, also, have been bred together, each pair being kept in a separate vessel. The young have all been examined for eye-colour, and the experiment has been continued to the fifth generation and beyond, well over a thousand young having been recorded. A black-eyed animal was never once found amongst them. Both the wild, black-eyed *Gammarus*, therefore, and the red-eyed variety, which arose in the Laboratory, breed perfectly true to type.

Red-eyed animals were mated with pure black, the cross being made in both ways, red female with black male, black female with red male. In the early experiments 3,779 young ones were examined and recorded. Without exception the eyes were black. Clearly, therefore, black is dominant and red recessive.

The black-eyed hybrids obtained from the cross between black and red were mated together. They produced altogether 4,393 young, of which 3,327 were black-eyed and 1,066 were red-eyed. (See Diagram 6.1.) This is a very close approximation to the 3 : 1 ratio. There are 32 reds too few on a total of 1,066 reds. This may be due merely to chance, or it may be due to the fact ascertained during the course of the experiments that the red-eyed animals are not quite as vigorous and healthy as the black-eyed. The deficiency in the number of reds may therefore mean that more red than black failed to survive whilst the eggs were developing in the brood-pouch of the mother.

1. **BLACK** CARRYING RED × **BLACK** CARRYING RED.

	Blacks.		Red.
Experiment .	3,327		1,066
Theory . .	3,294		1,098
	3	:	1

2. **BLACK** CARRYING RED × **RED.**

	Blacks.		Reds.
Experiment .	2,176		2,079
Theory . .	2,128		2,128
	1	:	1

3. **BLACK** CARRYING RED AND ALBINO × **BLACK** CARRYING ALBINO.

	Blacks.		Reds.
Experiment .	144		59
Theory . .	153		51
	3	:	1

4. **BLACK** CARRYING RED AND ALBINO × **RED** CARRYING ALBINO.

	Blacks.		Reds.		Albinos.
Experiment .	235		169		144
Theory . .	205		205		137
	3	:	3	:	2

5. **BLACK** CARRYING RED AND ALBINO × **BLACK** CARRYING RED AND ALBINO.

	Blacks.		Reds.		Albinos.
Experiment .	542		189		241
Theory . .	547		182		243
	9	:	3	:	4

6. **RED** CARRYING ALBINO × **RED** CARRYING ALBINO.

	Reds.		Albinos.
Experiment .	1,408		471
Theory . .	1,409		470
	3	:	1

DIAGRAM 6.

Eye-colour of *Gammarus*. Results of various crosses.

Hybrid blacks were mated with red-eyed recessive animals. (Diagram 6. 2.) 4,255 young were obtained and examined as soon as extruded from the brood-pouch. 2,176 were black-eyed, and 2,079 were red-eyed, which is very close to the equality which Mendel's theory demands. There is again a slight deficiency of red-eyes, namely 49.

This cross of the hybrid with the recessive, which we have already studied in the yellow and green peas, is a specially important one to anyone investigating problems of inheritance, because its result enables us to distinguish the pure dominant from the hybrid which in appearance resembles it. We have seen that the pure black mated with red gives all black offspring. If, therefore, when a black and a red are mated together we get some red-eyes amongst the children, we know that it is a hybrid black that we are dealing with.

One other mating of these two varieties remains to be considered. When hybrid blacks are mated with pure blacks, the dominant asserts itself completely, and all the offspring are black-eyed. The total number of young obtained in our earlier experiments from crosses of this kind was 379—all with black eyes.

In one family, belonging to the first generation of hybrids got by crossing the red-eyed *Gammarus* with the pure black-eyed one, a second sport or mutation appeared. The brood in which this mutation occurred consisted of 7 black-eyed young, 1 red-eyed and 4 in which neither black nor red pigment could be seen, and only the network of chalk-white pigment was left. (Plate VII, Fig. 4, of preceding paper.) The eye was also very irregular in shape and altogether of a degenerate character, the number of ommatidia being very few. These degenerate eyes, with only white pigment, we shall speak of as "albino" eyes.

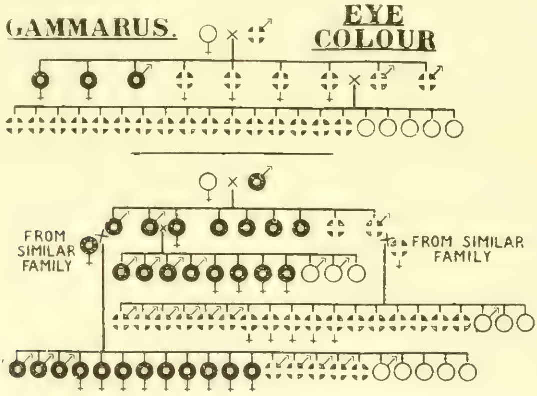


DIAGRAM 7.

A Black disc with white centre represents a black-eyed animal.
A Black disc with white cross represents a red-eyed animal.
A Black ring represents an albino-eyed animal.
♂ = male. ♀ = female.

In order to determine the constitution of these degenerate albino eyes, and to find out whether or not the condition was hereditary, one of the animals, a female, was mated first with a pure red male, and then with a known hybrid black one.

The result of these matings is shown on Diagram 7, and will probably surprise you. Albino-eyed female mated with pure red-eyed male gave 6 red-eyed and 3 black-eyed young. Albino-eyed female mated with hybrid black gave in four broods 75 black-eyed and 15 red-eyed young.*

In the grandchildren from both crosses, however, you will see that the albino-eyed form reappears.

From this it follows :—

(1) that the factor for albino eye is transmitted from parent to offspring, but that colour is dominant and albino recessive, for when albino is mated with coloured eye no albinos occur in the first generation of offspring ;

(2) that the original albino-eyed female must have contained the factor for black, since black offspring were produced when it was mated with pure red, which we know from the previous work contains no black ;

(3) that the albino-eyed female must contain the factor for red, and this for two reasons : in the first place, if it had contained black only we should have got only black offspring when it was mated with red, for we know that black is dominant to red ; in the second place, and again because black is dominant to red, if the albino had contained black only, when mated with the black hybrid we should have had only black offspring, whereas we obtained 75 black-eyed and 15 red-eyed. We know that when the hybrid, containing red and black, is mated with another hybrid of the same kind the resulting offspring should be 3 black to 1 red.

We must now look more closely at the grandchildren of the original albino-eyed female, which were all obtained by mating together her immediate offspring of the F.1 generation. When two blacks were mated together in F.1 two kinds of broods resulted, some in which only black and albino-eyed young occurred, others in which black, red, and albino were present. When two F.1 reds were mated together the broods contained red-eyed and albino-eyed young. (See Diagram 7.)

This resembles closely what is found in coat colour in animals such as rabbits, mice, and rats, which has been worked out by Bateson, Punnett, and others. To explain the phenomena these authors assume that in order that the colour in the coat of an animal may be visible it is necessary that at least two factors should be present, one factor representing the colour itself—say black or brown, as the case may be—and a second factor which must be present in order that the colour may show itself. In the absence of this latter factor, which they call the colour factor, the animal will be white, though it may still retain the power of transmitting a particular colour to its offspring. The black or brown factor is present in the animal's constitution, but in the absence of the colour factor the black or brown does not appear.

---

* In the diagram one brood only is shown from this mating, consisting of 7 black-eyed and 2 red-eyed young.

Pure **BLACK**	C B C B
Pure **RED**	C R C R
BLACK carrying red (Hybrid Black)	C B C R
ALBINO carrying black	c B c B
ALBINO carrying red	c R c R
ALBINO carrying black and red	c B c R
BLACK carrying albino	C B c B
RED carrying albino	C R c R
BLACK carrying red and albino	C B c R
BLACK no-white	w C B w C B
RED no-white	w C R w C R

Diagram 8.

Eye-colour of *Gammarus*. Constitutions of some of the different kinds.

C represents the factor for colour, **c** the absence of this factor.

B represents the factor for black, **R** that for red.

w represents the factor for absence of white pigment.

Animals of the first nine constitutions shown on the diagram all possess the white pigment, and this might have been indicated by adding $\genfrac{}{}{0pt}{}{\mathbf{W}}{\mathbf{W}}$ to the formula in each case.

A similar hypothesis will explain the present case. Diagram 8 shows the constitutions on this hypothesis of some of the varieties of *Gammarus* which have been obtained in the experiments. The colour factor is indicated by **C**, the absence of this factor by **c**. **C** is dominant to **c**. **B** and **R** represent the factors for black and red-eye respectively.

Just as we worked out on Mendel's theory the result to be expected from the crossing of yellow-wrinkled and green-round peas, so in this case we can work out the result from mating together animals with any two of these various constitutions. This has been done for all possible combinations, and the results of the experiments are in good agreement with theoretical expectations, as may be seen from a study of Diagram 6, which gives the numbers actually obtained from several of these matings, as well as those which the theory requires.

The black-eyed children of the original albino-eyed female mated to the hybrid male, all of which carry the factor for albino, or, to put it more accurately, lack one colour factor, can be crossed in three different ways :

(1) Pure black × Pure black.
(2) Pure black × Hybrid black (Black carrying red).
(3) Hybrid black × Hybrid black.

If we work out the theory for these crosses, just as we worked it out for the peas, we find that altogether amongst the offspring, that is amongst the grandchildren of the original parents, there will be animals of nine different constitutions of eye-colour (compare Diagram 8), namely :—

4 kinds of black-eyed animals .	Pure black. Black carrying albino. Black carrying red. Black carrying both red and albino.
2 kinds of red-eyed animals . .	Pure red. Red carrying albino.
3 kinds of albino-eyed animals .	Albino carrying black. Albino carrying red. Albino carrying black and red.

In the actual experiments we have been able to prove that animals of all these nine kinds occur, and the numbers also in which they are found are in sufficiently good agreement with the theoretical expectation to satisfy us of the correctness of the theory.

In Diagram 9 the actual results of a number of matings in which the albinos take part are shown, as these results are specially interesting.

Mated together the albinos give all albino offspring, whatever their constitution, since neither parent contains the colour factor, which we have indicated by great **C**, which enables the colour to appear.

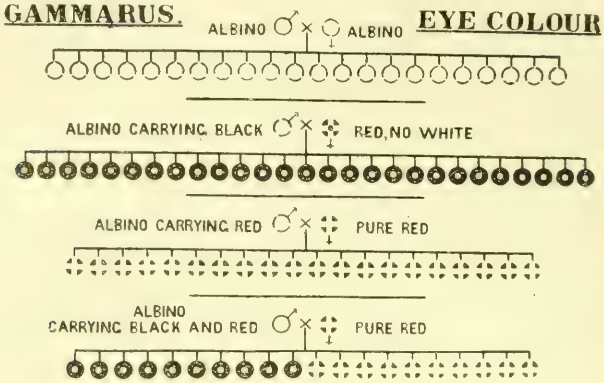

GAMMARUS.
ALBINO ♂ × ♀ ALBINO
EYE COLOUR
ALBINO CARRYING BLACK ♂ × ♀ RED, NO WHITE
ALBINO CARRYING RED ♂ × ♀ PURE RED
ALBINO CARRYING BLACK AND RED ♂ × ♀ PURE RED

Diagram 9.
(Signs as in Diagram 7.)

Mated with pure red, albinos give three kinds of broods :

(1) All black-eyed young. In this case the albino contains the factor for pure black, which is dominant to red.

(2) All red-eyed young. In this case the albino contains pure red.

(3) Black-eyed and red-eyed young in equal numbers. The albino is then hybrid as regards colour, containing factors for both black and red.

There is still another sport or mutation which has occurred in the eye of *Gammarus*. This is the entire absence of the chalk-white pigment which lies near the surface between the ommatidia. (Plate VII, Fig. 5, of preceding paper.) These we call " no-white " eyes.

Animals with eyes like this may be either black-eyed or red-eyed, and the black-eyed ones may be either pure black or hybrid black containing red. By cross-breeding we have obtained all three kinds.

The character " no-white " is transmitted to the offspring in strict accordance with Mendel's law, the presence of white pigment being dominant and its absence recessive. If an animal therefore which possesses the white pigment is mated with one which does not possess it the offspring in the first generation all have the white pigment—their eyes are quite normal. If males and females of this first generation are mated together, in their offspring—in the grandchildren of the original pair—" no-whites " reappear.

At this stage of the investigation a very interesting question arose. What would be the result of crossing the "no-whites" with albinos, and mating together their offspring?

We may represent the factor for white pigment by **W**, and its absence by **w**. These two factors behave as an alternative pair, according to Mendel's law. The constitutions of the black and the red "no-whites" will then be $\begin{matrix}\mathbf{w\,C\,B}\\ \mathbf{w\,C\,B}\end{matrix}$ and $\begin{matrix}\mathbf{w\,C\,R}\\ \mathbf{w\,C\,R}\end{matrix}$.

If we cross these with albinos and work out the theory, as in the case of the peas, we find that in the first generation we get all normal-eyed offspring, the "no-whites" provide the colour factor, the albinos provide the white.

The result of such a cross obtained in an actual experiment is shown in the Diagram 9 (the second brood shown on the diagram). The young are all normal-eyed blacks. They, however, differ in constitution from any black-eyed animals previously obtained, for they carry not only the factors for black and red but also the factors for both "albino" and "no-white," and are capable of transmitting all four factors to their children.

When these animals are mated together, according to the theory, which we can work out in the usual way, there should be, out of every 64 offspring, 48 with white pigment present, and 16 with no white pigment. Of these 16 with no white pigment 4 should be ALSO ALBINO, that is to say they should, according to the theory, show neither white, nor black, nor red pigment. The eyes should be quite colourless.

Animals with quite colourless eyes we had never seen when the theory for this cross was first worked out. Would they be produced when an actual experiment was made? A pair of these black-eyed hybrids was mated. The first brood hatched was a small one, but our pleasure was naturally great when we found that it consisted of 2 with normal black eyes, 1 black with no white, and 2 quite colourless, with no eye-pigment visible at all. Since then other broods have been obtained, and there is no doubt that the facts agree with the theoretical analysis.

Looked at from a general point of view the cross of the "no-white" with the albino-eye is of great interest, and is particularly instructive. We here took the two most degenerate and abnormal types of eye that were known, and mated together the animals which carried them. In the first generation the offspring have all perfectly normal characters and are indistinguishable, as far as their own visible structures are concerned. from the perfect wild creatures. The factors lacking in one parent were supplied by the other parent and perfect children resulted. The defects, however, persist in a latent condition in the germ plasm of these children, and if they are mated with those of like constitution the defective characters all reappear in the grandchildren. The factors may even combine in such a way that some of these grandchildren are more defective than the defective ancestors from which they sprang. They unite the defects which were borne separately by the two grandparents. This no doubt explains some of the ill-effects which result from too close inbreeding. We should remember, too, that if here defects have been united, in other cases it would be equally possible that the excellences of different ancestors should be combined in some of their descendants.

With *Gammarus*, however, what we have actually observed has been a degeneration of the eye, taking place step by step as one factor after another has been lost. Bateson, in his presidential address to the British Association in Australia in 1914, emphasised the fact that most, though perhaps not all, the Mendelian cases studied up to the present can be explained rather by the loss of factors than by the introduction of new factors. Since that address was delivered there has been, shall we say, in the air—for no one has ventured, I believe, to declare himself a complete adherent to it—a theory of a kind of inverted evolution, starting with a highly complex primitive protoplasm or germ plasm, which by the loss of factor after factor has given rise to the endless varieties of plants and animals that we know. These factors are conceived of as being for the most part restraining or inhibiting factors, whose loss, one by one, in the course of ages has allowed the full powers and glories hidden in the primitive plasm to unfold themselves—a process which still goes on. What the final excellence or final catastrophe is to be, when all the bonds are broken and all the restraints are lost, no one, as far as I know, has ventured to suggest. When, however, we take into consideration the whole range of facts upon which our conceptions of organic evolution are based we find little to support such a view.

The cases of Mendelian inheritance which I have so far discussed have been of a simple character, following exactly the law which Mendel first laid down. Sometimes, however, the phenomena are more complicated. We saw that the albino-eye of *Gammarus* was always imperfect in shape. Absence of colour and imperfect form are here always united and remain united in inheritance. Characters which behave in this way are spoken of as linked characters, and the factors in the germ cells from which they originate are also said to be linked. There is often also a special connection between a particular character and the sex of the animals which transmit and inherit it. This is known as sex-linkage and is well illustrated by eye-colour in the American fruit fly *Drosophila.* The wild fly has red eyes, and a sport or mutant is known which has white eyes. If a white-eyed male is mated with a red-eyed female all the offspring are red-eyed, and males and females occur in equal numbers. When these hybrids are mated together there result three red-eyed flies and one with white eyes—the usual Mendelian proportions. The white-eyed flies, however, in this generation are all males, like the grandfather. If however we make the original cross in the opposite way, mating a red-eyed male with a white-eyed female a different result is obtained. Instead of having all red-eyed children, males and females in equal numbers, we have equal numbers of white-eyed males and red-eyed females. In the next generation also the result is different, for when one of these red-eyed females is mated with a white-eyed male the offspring are red-eyed females, red-eyed males, white-eyed females and white-eyed males in equal numbers. It would carry us too far were I to attempt to give the explanation which has been put forward to account for this, so I shall content myself with stating the facts to show that the simple Mendelian law may at times seem to give highly complex results.

That knowledge gained by Mendelian investigations may be of great value to practical agriculture is shown by Prof. Biffen's work on the varieties of wheat. The wheats usually grown in England produce heavy crops, but the flour obtained from them is not satisfactory from a baker's point of view. A loaf made from this flour does not rise well when baked. In order to correct this it is usual to mix the English flour with flour from a so-called " hard " foreign wheat, which contains a larger proportion of gluten. English wheats, also, are very liable to a disease known as " rust," which is caused by the growth of a fungus on the plants. Prof. Biffen was able to show that good cropping power, hardness, and ability to resist rust are all characters which behave in a Mendelian way. By a long series of experiments in crossing different varieties of wheat he was able to produce a variety which possessed good cropping powers, the hard qualities of foreign wheat, and also a complete power of resisting rust. This wheat can be grown quite successfully in the English climate, and it has kept its special qualities unchanged for a number of years.

And now for a few minutes we will direct our attention to the question in connection with this subject of Mendelian heredity, which is perhaps of more interest to us than any other. In the human race does inheritance take place in accordance with Mendel's law ? There is considerable evidence that certain characters do follow this law and that the same thing is true of certain diseased conditions.

The inheritance of eye-colour is a striking instance, which was investigated in this country by Hurst and in America by Davenport. Hurst examined the eyes of children in a Leicestershire village, and also the eyes of their parents and grandparents, where that was possible.

The iris, the part of the eye in which the colour is situated, owes its colour to two separate layers of pigment, a deep-seated layer which gives the effect of blue, and a layer near the surface which contains yellow and brown pigment. When the brown pigment of the surface layer is fully developed it hides completely the blue underneath it, and the eyes are dark brown in colour. If the brown pigment is entirely absent we get the true blue eye, and such an eye Hurst calls *simplex*. Eyes with both blue and brown pigment he calls *duplex*, and these duplex eyes are of two kinds. First, those in which the brown completely covers the iris and hides the blue, the so-called self-coloured or whole-coloured eye, and second, eyes in which the brown pigment forms a ring round the black pupil in the centre of the eye, whilst the greater part of the blue layer can still be seen. Such duplex eyes are called "ringed." The details of distribution of eye-colour in two of the families examined by Hurst are shown in Diagram 10.

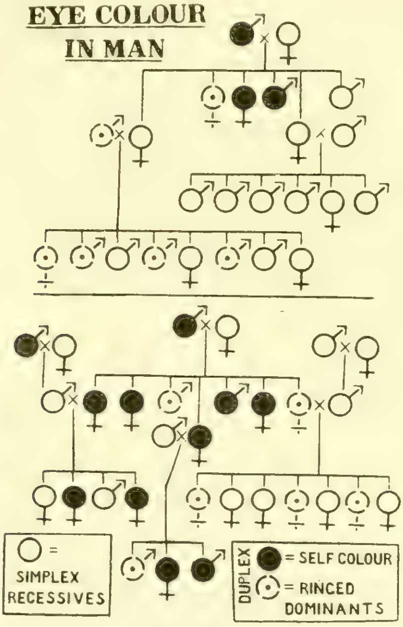


Diagram 10.

These and other results which were obtained showed that whole-coloured brown eyes were always dominant to ringed and also to blue. Ringed eyes were also dominant to blue. The blue simplex eyes were pure recessives, and whenever father and mother both had such eyes all the children also had eyes of the same kind.

The dominant self-coloured and ringed eyes, on the other hand, might be either pure dominants, or hybrids containing the factor for recessive blue eyes. Several instances of these hybrids are seen in the diagram.

The next diagram (Diagram 11), which is extracted from a much larger pedigree illustrated by Bateson in his book on "Mendel's Principles of Heredity," shows a portion of the pedigree of a family living in a cluster

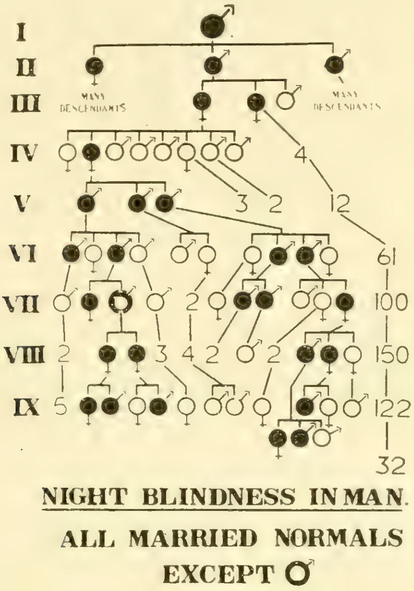


Diagram 11.

The black discs represent the affected individuals, the rings those who did not suffer from the disease. In the exceptional case (black disc with white centre) both parents were affected. The arabic figures indicate numbers of unaffected children. Nine generations (I–IX) are illustrated.

♂ = males, ♀ = females.

of villages in the south of France, in which many members have suffered from what is known as night-blindness, the affected persons being quite unable to see in a dim light. The pedigree commences with one Jean Nougaret, born in 1637, and has been followed through ten generations. In this family the disease has always behaved as a Mendelian dominant, though not a simple one, and it has always been inherited from an affected parent. Unaffected parents have never had affected descendants.

In another disease, hæmophilia, there is a curious relation with sex.

The symptom of the disease is that the blood refuses to clot, and hence there is great loss of blood from even a very slight wound, such as a scratch. The peculiarity about its inheritance is that only the male members of a family are affected, but the disease is usually transmitted through the females, who do not themselves develop it. An apparently healthy daughter belonging to such a family will transmit the affection to her sons, and her daughters will be capable of handing it on to their children.

If we pass from a consideration of man's physical nature and ask ourselves whether and to what extent the principles we have been discussing are applicable to his moral and intellectual qualities, we enter a field of speculation of the very highest interest. In his work on "Hereditary Genius," published in 1869, Francis Galton brought together and analysed a great mass of information which proved conclusively that excellence in many intellectual and moral qualities occurred in particular families with a frequency out of all proportion to that in which it was found in the general population. No one will, I think, dispute the fact that musical ability is inherited in certain families, and the same seems to be true of mathematical genius, though by no means all the nearly related members of the families possess the exceptional powers. Galton gives a list of 36 men who took the place of senior classic at Cambridge between 1824 and 1869. In this list of 36, the name Kennedy occurs four times, three of the men being brothers and the fourth a nephew of the others. The name Lushington occurs twice, the men being brothers, whilst a third brother was fourth classic of his year.

Mendel's law was unknown to Galton when this book was written, but a consideration of his data certainly suggests that some at least of the exceptional mental and moral attributes with which he deals may follow the general principles of inheritance which Mendel first made clear. The question is one which may well repay further investigation. And if the future should reveal to us with certainty the fundamental principles according to which human qualities, both physical and mental, are handed on from generation to generation, shall we not have reached a real landmark in the progress of the human race towards well-being? It is not that one contemplates direct interference with the liberty of the individual, excepting perhaps in extreme cases of physical or mental disease, but we may, I believe, look forward to a gradual incorporation in the traditions and social usages of the people, of such knowledge as shall come to stand on a certain and indisputable scientific basis. The immense power of such traditions and customs on the life of the general population cannot be denied. Gradually, too, as the new facts become firmly established, religious teachers will lend their aid, and ethical thinkers will submit that a high standard of morality demands that the welfare of unborn generations shall not be sacrificed. Man, it is true, is prone to follow desire rather than reason ; but all these influences should not be without effect in producing a definite progressive improvement in the inborn qualities of the race. Such at least would seem to be the possibilities opened up by the detailed study of the laws of heredity.

Food from the Sea.

Being the Presidential Address delivered before the
Plymouth Institution, October 14th, 1915.

By

E. J. Allen, D.Sc., F.R.S.,
Director of the Plymouth Laboratory.

[Reprinted from the Transactions of the Plymouth Institution.]

. . . PASSING now to the special subject of my address to-night, I will ask your attention in the first place to some general aspects of our Sea Fisheries as a source of national food supply and to the general scientific investigations which have been undertaken in the hope that the yield of the harvest of the sea may be still further increased. In the second place a more detailed account will be attempted of some particular researches bearing upon these matters, which happen to have formed during the past few years the subject of my own special work. If in the course of my remarks you may seem to be asked to follow me in excessive detail into some of the more remote corners of the problems which arise, my excuse must be that, even at the risk of upsetting the balance of the picture as a whole, it is probably possible to speak to more purpose and with a better prospect of stimulating others to fresh efforts, by describing researches with which I have been personally concerned, than by a more general and better proportioned, but necessarily more superficial treatment of the whole subject.

As a direct consequence of our geographical position, our immediate proximity to large areas of shallow sea, our extended coast-line, with its many fine harbours and serviceable fishing coves, lying at distances not too remote from the large centres of population, and of our well-developed railway systems, the sea fisheries of Great Britain have become of much greater relative importance as a source of food supply than has been the case in almost any other country of the world. The statistics for the year 1913, the last complete year for which normal figures are available, show that 1¼ million tons of fish were landed in England, Scotland and Ireland, having a value at the port of landing of some 15 million pounds.

By way of comparison, and to give you some idea of the relative importance of the industry, similar figures for one or two other sources of our food supply may be of interest. In the same year 1913, 1½ million tons of wheat were grown in the United Kingdom, as against the 1¼ million tons of fish landed, the wheat being valued somewhere about 13 million pounds, as against 15 million pounds for the fish. Imported wheat was 5¼ million tons, valued at 44 million pounds. Imported beef was valued at 16 million pounds, imported mutton at 11 million.

It should be added, however, that one-third of the total value of the fish landed is attributable to herrings, which were salted and exported chiefly to Germany and Russia, the sum received for these fish being 5 million pounds.

It is interesting to compare the value of fish landed in the United Kingdom with that of fish landed in other European countries. Of the total value of sea-fish landed in Europe in 1910, 47½ per cent (very nearly one-half) stands to the credit of British fisheries, other countries showing France, 19 per cent; Norway, 10 per cent; Germany, 7 per cent; Holland, 7 per cent; Sweden, 3 per cent; Denmark, 3 per cent; Belgium, 1 per cent; Russia, 1 per cent.

From these figures you will see what a preponderating part our islands take in the total yield of the fisheries.

Now the two pressing questions which present themselves, from the practical point of view, are: Do we at present make the best possible use of the harvest of the fishing grounds? And how can the yield of human food in the form of fish be increased?

As a matter of fact from year to year, for many years past, the total quantity and the total value of the fish landed in this country have both shown a steady and continuous increase. Even since the year 1890, when the industry of steam-trawling was already in full swing, the total landings have doubled both in quantity and in value. This increase has been brought about entirely by increasing the number and the power of the fishing vessels and extending the areas over which they have worked. To-day the region worked by the steam-trawlers, which bring their fish in ice to the English market, extends northwards to the Barent's Sea, off the north coast of Russia—the so-called White Sea grounds—to Iceland and the Faroes, and southwards through the Bay of Biscay to the banks off the coast of Morocco, trawling being carried on to a depth of 200 fathoms or even more. Doubtless this process of increasing the power of fishing vessels and extending the area over which they fish will still continue. Trawlers have already made experimental voyages to the Banks of Newfoundland, and halibut from the Pacific Coast of Canada has been sent in a frozen state to the London market. This kind of development of the fisheries may well be left to the energy and enterprise of the fishing industry. The only useful help which the scientific expert might give, would be in making preliminary explorations of more distant grounds. Government has, however, never thought it right to provide public funds for work of this character, and it is probably better to leave it to the trade and the practical fishermen.

The subject with which fishery science is called upon to deal is rather, whether the best possible use is being made of the resources of food which the sea is capable of yielding in those waters in which fishing is already extensively and exhaustively carried on. British researches have dealt chiefly with the North Sea, the Irish Sea, the English Channel and the waters around the Irish coast. Are the methods of fishing now employed in these areas unnecessarily wasteful of fish life or could the total annual landings be made more valuable by a more rational regulation of the methods of capture? Are there other means, analogous to the cultivation of the land, which might be adopted to improve the yield of the fishing grounds and to what extent could such means be profitably employed?

It must be at once admitted that, except to a very limited extent, we are not at present in a position to give definite answers to these questions. We cannot assert with confidence that any attempted regulation of the fisheries upon a considerable scale has been followed by marked and definite improvement. In matters of cultivation also, excepting as regards some of the fisheries for shell-fish, such as oysters and mussels, we are unable to point with certainty to any success upon a large scale, when dealing with sea fish.

And the reasons for this comparative inability to obtain favourable practical results are not far to seek. In the first place, the sea is so vast and so powerful are its elemental forces, that control by human agency must always be immensely difficult. We should not forget, however, that the evidence is now almost conclusive that human agency has been powerful enough to exert a marked adverse influence upon many of the best and most productive fishing grounds, and if destruction can be wrought by man, it should not be beyond his power to do something to repair the damage he has caused.

In the second place, our knowledge of the many complex factors with which we have to deal is still very imperfect. It is, indeed, only very slowly approaching a point when proposals for practical measures can be made with any hope of foreseeing what the actual effect of those proposals would be. In this direction much further enquiry and study will be required. Notwithstanding all that has been done in the way of research during the last thirty or forty years the gaps in our knowledge on many of the most fundamental points are very great. Until more adequate means can be secured for carrying out actual experimental work at sea progress cannot possibly be rapid, and many of the problems cannot be studied in a satisfactory way.

Slowly, however, we are building up a true science of the fisheries. The direction and velocity of the currents, the differences in temperature and salinity of the water, and the variations in these factors from season to season and from year to year upon which the fluctuations in the abundance of fish must very largely depend, are being gradually worked out and understood. The effects of wind and weather and of the varying amount of sunshine falling on the water in different years are questions which are being studied. Then again, the natural history of the fishes themselves is the subject of much research ; their habits and food, when and where they spawn, the characters of the larval fishes and when and where their younger stages are to be found, all fall under this head.

Many of the results of investigations on these lines have already from time to time been described and discussed at the meetings of our institution, and for that reason I will not to-night dwell upon them, important —indeed, essential—as they are for an adequate understanding of the problems which have been put forward. It is to a more general aspect of the matter that I would especially refer—the question of how the primary or fundamental food supply of the sea is built up. Suppose that during the late summer or autumn we capture in the waters of Plymouth Sound, a mackerel. The body of that mackerel represents some 8 ounces of excellent human food. What is the ultimate source from which that food has been produced ? If we examine the stomach of the mackerel, we shall probably find it filled with small fishes, chiefly sprats and quite young herrings, with perhaps a certain number of those small, shrimp-like creatures which are known as Copepods. The young herrings and sprats have themselves fed largely upon Copepods of a similar kind. We conclude, therefore, that the body of the mackerel has been formed either directly, or indirectly, through the young herrings and sprats, from the organic substance contained in the bodies of the shrimp-like Copepods. Then if we carry the problem a stage further back and enquire how the bodies of the Copepods have been built up, we find with the aid of a microscope that their food consists in large measure of minute plants, chiefly belonging to the class of diatoms.

We have here a particular and perhaps exceptionally simple and straightforward example of the general principle, applicable equally to land and sea animals, that the organic substance which constitutes their flesh is always derived either directly or indirectly from vegetable life.

The amount of animal life, therefore, which a given area of sea or land can support, depends upon the amount of plant life on which the animal life can feed.

When we push the enquiry further back we find, as you know, that the bulk of the plant substance consists, in addition to water, of compounds of the element carbon, which are known under the general name of organic compounds. This carbon is derived entirely from the carbonic acid gas present in the air or dissolved in the water, the gas being split up and the carbon assimilated by the plant in the presence of sunlight. The source of the energy by means of which all organic matter is built up is the light of the sun, whilst the great mass of the solid substance contained in the bodies of both animals and plants is derived ultimately from carbonic acid gas, obtained in the case of land plants from the air, in the case of sea plants from gas dissolved in the water. In addition to carbon and water the plant requires a number of other substances, chiefly inorganic salts, but the quantities of these which are necessary are comparatively small. In the case of land plants these salts are obtained from the soil, in the case of sea plants from the water in which they are dissolved.

It may be interesting here to compare the yield of organic substance derived from a given area of sea or fresh water with that from a similar area of land, to compare the harvest of the sea with the harvest of the land.

It has been calculated by Brandt, from the catches of fishermen in an enclosed harbour, that the annual yield was 89 lbs. of fish per acre. In Continental carp ponds, where the culture has been carefully carried on, 95 lbs. of fish per acre per year have been obtained.

Making a similar calculation for the North Sea from the statistics of fish landed, we get, as we should expect, a much lower annual yield, namely, 15 lbs. of fish per acre. The average value of this is only 1s. 6d. per acre per year.

Beds of shellfish give a very much higher yield, but they of course in reality, owing to the tidal currents which pass over them, draw their food supply from a much greater area of water than that of the sea-floor to which they are attached. Johnstone finds for the uncultivated mussel beds of Morecambe Bay, on the Lancashire coast, a yearly production of 86 cwts. (or nearly 10,000 lbs.) per acre, valued at £14 16s. per acre.

For comparison with these figures here is one taken from agricultural statistics. Young bullocks fed on cultivated land give an average annual yield of 73 lbs. of beef per acre.

Putting the figures side by side we have first the mussels from Morecambe Bay, with a yearly production of 10,000 lbs. per acre; then in quite a different category:—

Fish from Carp Ponds	95 lbs.	per acre	per year.
Fish from the enclosed Harbour .	89 lbs.	,,	,,
Beef from Young Bullocks . .	73 lbs.	,,	,,
Fish from the North Sea . . .	15 lbs.	,,	,,

It will be seen, therefore, that although the figures for the open sea are far below those for cultivated land, more restricted areas of water are capable of producing a considerably greater weight of crop. Especially the figures for the mussel beds seem to indicate that much larger returns from the sea might be possible, if sufficient knowledge of the complex conditions of marine life could be successfully obtained.

The possibilities of a still greater yield have recently been suggested by Prof. Benjamin Moore of Liverpool, from observations made in the Irish Sea. This author has calculated from measurements of the change in alkalinity of the water, that under the action of sunlight there is an annual production of two tons of dry organic matter per acre, which would be equivalent to at least *ten tons* of moist vegetable substance. This is a preliminary estimate to which it would be unwise to attribute too great exactitude at present, but it does seem to confirm the view that we are as yet a very long way indeed from making full use of the organic food substance which the seas around our coasts are capable of producing.

And this leads me to ask your attention in a little more detail, to the particular aspect of the conditions upon which marine life depends, to which my own researches have recently been directed.

The marine vegetation, which constitutes the fundamental food supply of the sea, may be divided into two principal groups. All round our shores we find attached to the sea-floor the green, red and brown seaweeds. These form a fringe in the shallow water around the coast, but do not extend to a greater depth than about 15 fathoms, owing to the fact that sufficient light to enable them to grow does not penetrate through the water below this depth. Many animals feed upon these seaweeds as they grow, and recent researches by Danish naturalists seem to show that when the weeds die and decay the organic fragments into which they break up constitute an important source of food for many other animals, which in their turn serve as food for fish.

Outside this coastal fringe, however, the plant life of the sea consists of minute organisms, microscopic in size, which float freely in the water, and live and grow in the upper layers from the surface to a depth of 100 or 200 fathoms, or even deeper. Amongst these microscopic plants one of the most important and prolific groups is that of the diatoms. These plants possess a delicate and often very elaborately constructed skeleton of silica, and contain a brown colouring matter, which like the green chlorophyl of land vegetation is able in the presence of sunlight to assimilate the carbon from carbonic acid gas.

It has formed an interesting subject of research to endeavour to ascertain as exactly as possible the conditions necessary for the growth of these diatoms, and to find out by means of experiments in the laboratory how the amount of growth may be increased. In order to carry out such experiments with exactitude and to obtain precise and definite results it is necessary to work with cultures of a diatom which are as nearly as possible pure, that is to say, cultures which contain no other living organisms excepting the single species of diatom upon which the experiments are being made. If two or more living organisms are present in the experimental cultures the results at once become complicated, since a second organism not only uses up the different constituents in the culture solution, but it also excretes waste products of its own, which become dissolved in the water and may affect either favourably or unfavourably the growth of the diatom which is being experimented upon.

The experiments had, therefore, to be conducted as nearly as it was possible under sterile conditions. The glass flasks in which the cultures were made, after being carefully cleaned, were baked in an oven, and all the culture solutions were boiled before being used.

The particular diatom upon which the experiments were made is one that is found in the Plankton, that is to say amongst the large number of microscopic organisms which float freely in the waters of the sea, and are drifted about at the mercy of wind and current. Such organisms are collected by dragging through the water a bag-shaped net, made of muslin or fine-meshed silk, which strains them out. This form of net is generally known as a tow-net. The organisms collect in a tin or bottle attached to the end of the net, and can be brought alive to the laboratory in a bottle of sea-water.

The species of diatom used in the experiments is called *Thalassiosira gravida*. Each diatom cell consists of two flat, cup-shaped valves, fitting one into the other and enclosing the protoplasmic substance of the cell. The whole cell of *Thalassiosira* looks something like a flat, shallow pill-box. A number of these cells are joined together by threads, which run from the middle of one cell to the middle of the next, so that long chains are formed. These chains of diatoms have much the appearance of a number of buttons strung on a thin wire, with a considerable interval between successive buttons. This chain formation is of some importance in the experiments, because the length of the chains which are formed gives a good indication of the healthiness of the culture.

In order to obtain a pure culture of a Plankton diatom two methods may be used. The first—which, however, does not give very satisfactory or certain results in practice—is to pick out under the microscope, by means of a very fine glass pipette, a single cell or short chain of the diatom and put it in a flask containing a suitable culture solution.

The second method, which is the one I have more often used, is as follows: A glass flask, containing about 2 litres (say, half a gallon) of suitable culture solution, the nature of which I shall describe presently, is brought to the boil in order to kill off any animals or plants which may be present in it, and then allowed to cool. We then take some sea-water containing a mixture of Plankton animals and plants, which have been collected with a fine silk net in the way already described, and add just one or two drops of it to the flask containing the half-gallon of cold culture solution. The flask is shaken up, and the living organisms, which were present in the two drops of sea-water, become evenly distributed through it. The water in the flask is then divided up, by pouring it into, say, forty or fifty tiny flasks, and these small flasks are put to stand in a north light and kept at an even temperature. After a week or ten days a brownish growth appears in many of the flasks, and if the experiment is successful, that is to say if our one or two drops of water containing the mixture of organisms has been sufficiently divided up, we shall find in perhaps two or three of our fifty small flasks a pure culture of one of the Plankton diatoms. A culture once obtained in this way can be kept as long as we wish, by continually inoculating new flasks of sterile culture solution, transplanting to one new flask after another as often as may be desired. I have kept cultures alive in this way for six or seven years.

Such cultures are, however, not quite perfect. They always contain in addition to the diatoms some bacteria, and these are very difficult to get rid of; indeed I have never really succeeded in entirely eliminating them. They may be greatly reduced by a process of differential poisoning. By adding to a series of culture flasks gradually increasing doses of chlorine gas, it is possible to hit off a strength of the poison which will kill most of the bacteria without killing the diatoms. In this way a culture of the diatom *Thalassiosira* was obtained in which there remained only one kind of micro-organism, or at least only one kind that could be detected in the ordinary way by growth on agar-agar plates. The experiments to be described were made chiefly with this culture. Its growth was very rapid and healthy under favourable conditions, and very long chains of diatoms were formed.

Previous work dealing with the culture of diatoms had been done mainly by the French bacteriologist Miquel. Miquel himself investigated principally fresh-water diatoms, but he showed that the methods he employed could be used also for marine forms, his experiments in this direction having been made chiefly with shore and bottom species. My own work, in which during the earlier stages I received much assistance from my colleague, Mr. E. W. Nelson, has dealt mostly with the floating or Plankton diatoms, which are much more delicate organisms to deal with than the fresh-water or marine bottom forms.

Miquel showed that fresh-water diatoms could be most successfully grown when to the water there was added a very small quantity of certain inorganic salts, together with a small proportion of soluble organic matter, prepared by making an infusion or maceration of straw, bran or some other vegetable substance.

The inorganic salts, which Miquel considered necessary, were the following:—

Magnesium sulphate
Sodium chloride
Sodium sulphate
Ammonium nitrate
Potassium nitrate
Sodium nitrate
Potassium bromide
Potassium iodide

Sodium phosphate
Calcium chloride
Ferric chloride

Of these salts the most important were found to be the nitrates, the phosphate and the iron salt, a result which agrees with what we know of the requirements of plant-life in general. These three substances, especially the nitrates and phosphate, are as is well known largely used by farmers as artificial manures.

In order to grow marine diatoms, Miquel added to sea-water the same salts which he had used for growing fresh-water diatoms. Our experiments have shown, however, that it is by no means necessary to add all these salts to sea-water in order to get good cultures. Quite as good results can be obtained by the addition only of Potassium nitrate, Sodium phosphate and Iron chloride, the two latter being made into solution with calcium chloride and hydrochloric acid, according to a special method described by Miquel.

If sea-water which has been obtained near the coast is used as the basis for the culture medium it is not necessary to add an infusion of organic matter.

The actual quantities of inorganic salts added to the sea-water are really very small, those employed in our later experiments being in 100,000 parts of sea-water :—

40	parts	of	Potassium nitrate.
4	,,	,,	Sodium phosphate.
1	,,	,,	Calcium chloride.
2	,,	,,	Ferric chloride.

When the culture solution has been prepared it is first boiled in order to kill off any organisms it may contain, and a precipitate which forms is allowed to settle. The clear water is then poured off into small flasks, in which the experimental cultures are made, a second boiling being carried out before the flask is inoculated with the diatom culture. The diatoms grow best at a temperature of about 60° F., in a good north light. They must not be exposed to direct sunlight, as in the small flasks used this is found to kill them.

The culture solution just described has sea-water for its basis. Now sea-water is a very complex solution containing both inorganic and organic substances, and although it is true that the relative proportions of the predominating salts are remarkably constant everywhere in the sea, there are present in it also, often in very minute quantities, many other important substances which are subject to considerable variation from place to place and from time to time. These varying substances are in many cases just those which are of special importance to the living plant. They occur often in such minute traces that it is practically impossible to measure accurately by means of chemical analysis the quantities in which they are present.

In order, therefore, to study the effect on the growth of the diatoms of very small quantities of various substances a different method of procedure was adopted. Instead of using natural sea-water as the basis for the culture solutions, an artificial sea-water was built up by dissolving in pure distilled water the purest chemicals that could be obtained. The distilled water was made specially pure by distilling it a second time in all-glass apparatus, so that it did not come in contact with any metal such as tin or copper. Further, when being distilled for the second time, the water was boiled with bichromate of potash and sulphuric acid in order to destroy as far as possible any volatile organic matter what it might contain. By taking the right proportions of the pure chemicals and dissolving them in this doubly distilled water an artificial sea-water was made having as nearly as possible the composition of natural sea-water. It was, of course, also possible to make up artificial sea-waters of different compositions, one or other of the constituent salts being increased or diminished in amount, or omitted altogether.

What we may call the normal artificial sea-water, that is, the one with a composition as nearly as possible that of natural sea-water, had the following constitution :—

Sodium chloride	28·13	grams	per litre.
Potassium chloride	·77	,,	,,
Calcium chloride	1·2	,,	,,
Magnesium chloride	2·55	,,	,,
Magnesium sulphate	3·5	,,	,,
Sodium bicarbonate	·11	,,	,,

To this there was added in some of the experiments a trace of Potassium iodide and Potassium bromide, but the results did not seem to be affected by this addition.

There is another substance which requires careful consideration when we are dealing with diatom cultures. The skeleton of a diatom is composed of Silica, so that to get a healthy growth that substance must be supplied. An Austrian botanist, Richter, has shown that when cultures are made in glass vessels, enough silica dissolves from the glass to supply the diatoms with all they require. In my experiments I found that the addition of silica in other forms to the culture solutions appeared to make no difference to the growth. We may therefore in what follows disregard the silica, remembering that all the needful supply of it could be obtained from the glass of the flasks in which the experiments were made.

Having made the artificial sea-water in the way described the essential constituents of Miquel's solutions—Potassium nitrate, Sodium phosphate and iron—were added. After boiling and cooling, the flasks containing the solution were inoculated by adding a small quantity of a culture of the diatom *Thalassiosira*, which was already growing in natural sea-water. The flasks were then placed in a good light and the cultures given an opportunity to develop.

In the early experiments the results were very uncertain and difficult to understand. In most cases there was an entire failure of growth, but every now and then quite a good growth was obtained. It was noticed also that a good growth more frequently resulted when a flask which had failed was inoculated a second or a third time. It remained for a long time a puzzle why the cultures should generally fail but occasionally succeed, until it occurred to me that the quantity of natural sea-water transferred to the artificial sea-water when the latter was being inoculated was not always quite the same, and that when a culture was inoculated two or three times a much larger quantity of natural sea-water was introduced than when it was inoculated only once. Was it the addition of this increased quantity of natural sea-water that enabled the diatoms to grow in the purely artificial solutions ? Definite experiments were made to determine this point, and it soon appeared that the previous irregularity of the results could be accounted for in this way. It was found that if the inoculations were always made by adding only a very small quantity of the liquid from which the living culture was taken, say, by adding just one or two drops of culture to a flask containing 75 cubic centimetres of artificial sea-water, only a very slight growth, if any at all, took place. If, however, before the artificial water was inoculated in this way, and also before it was sterilized by boiling, as little as 1 part in 100 of natural sea-water was added to it, the diatoms grew well and excellent cultures were obtained. With 4 per cent of natural sea-water added to the purely artificial solution the cultures were quite as good as, if not better than the best that were got when natural sea-water was used entirely as the basis of the culture solution.

This result is somewhat remarkable because it seems to show the absolutely essential importance to the growth of the diatoms of an extraordinarily minute trace of some substance which exists in the natural sea-water. In the artificial water all the salts were included that occur in natural sea-water in any quantity above a mere trace—a trace so small that it is hardly capable of accurate measurement. Yet when this trace of substance is diluted down by adding 1 part of it to 100 parts of artificial sea-water, there is still enough of it introduced to make a vigorous and abundant growth possible where no growth at all was possible without it. This substance can hardly itself be regarded as a food substance. Its real action can only be conjectured, but we may think of it as a growth stimulant without the aid of which the plant is unable to build up its structure out of the real food substances.

In the course of further experiments it was shown that, provided this small quantity of natural sea-water were present, the composition of the artificial sea-water could be altered to an extraordinary extent without much if any effect being produced on the culture. In the first place the density of the artificial water could be changed within very wide limits without affecting the cultures appreciably. The solution might be diluted to one-half the normal strength or even below, or it might be concentrated so as to increase the density by as much as 50 per cent.

All the Potassium chloride might be omitted or the amount of Potassium chloride might be doubled. Similarly the Magnesium sulphate could be omitted or doubled without detriment. In the case of the Calcium chloride, also, the amount of permissible variation was very great, though not quite so great as with the Potassium chloride and Magnesium sulphate. These results were a little surprising, as it had generally been assumed that the Plankton diatoms were particularly sensitive to changes in the composition of the medium in which they live. It is clear, however, that provided all the essential substances are present, in some cases even excessively minute quantities being sufficient, the composition of the medium can be very greatly altered without affecting the organisms.

Incidentally, the facts which I have been describing would appear to have an important bearing upon all theoretical questions concerning the relation of the organism to its environment. If such a minute change in the environment as is involved in the addition of 1 per cent of natural sea-water to the artificial solutions can make all the difference between reproduction and no reproduction of the diatom, can we be said in the case of any organism whatever to have an adequate conception of what the effective environment really is? Clearly we are very far indeed from appreciating or understanding how intricate and varied are the many factors upon which the life of even the simplest plant or animal depends.

But this is a digression. Let us return to the diatom cultures, and ask what is the chemical nature of the essential substance, a trace of which must be present in the artificial culture solution before the diatoms can flourish. Up to the present I have been unable to give any final or adequate answer to this question. Certain hints and suggestions have, however, been obtained which give us an indication of the lines upon which the answer to the question is to be sought. Some of the experiments which have given rise to these suggestions may be of interest to you.

To a flask containing some of the artificial sea-water, which had been treated with nitrate, phosphate and iron, a small fragment of the green seaweed *Ulva* was added and the liquid boiled for a few minutes. A slight infusion of seaweed in the artificial sea-water was thus made. The piece of *Ulva* was removed and the liquid allowed to cool. It was found that good cultures of the diatom could then be made in the solution. The slight infusion of vegetable matter therefore performed the same function as the 1 per cent of natural sea-water, which had been added in the previous successful experiments.

When, on the other hand, instead of making an infusion of the seaweed as a whole, a piece of the seaweed was burnt and the resulting ash added to the artificial solution, the diatoms did not grow.

These two experiments together make it probable, though they do not completely prove the point, that it is an organic extract of the seaweed, and not some inorganic salt dissolved out of it, which has made the artificial solution a suitable medium for diatom growth.

In other experiments it was found that if instead of adding a small quantity of natural sea-water from the open sea, the same quantity of sea-water taken from the tanks of the Aquarium were added, the resulting diatom cultures were larger and more vigorous. The Aquarium water seems therefore to contain more of the substance whose nature we are trying to determine than the water from the open sea. Now in the Aquarium animal life is more concentrated than in the sea outside, and one chief difference between Aquarium water and that brought in from outside is that the former contains more of the waste products of animal life. The suggestion here again is that the substance we are seeking is an organic substance, a substance produced by some living organism—in this case a waste product of the living fish.

It must, however, be one of the more stable organic substances, for it was found that if some of the Aquarium water was evaporated to dryness and the remaining salt heated to a comparatively low temperature, say, to 200° C., and then again dissolved in distilled water, the solution thus obtained was practically as effective as natural sea-water in promoting diatom growth. The effective substance therefore can be dried and heated to at least 200° C. without being destroyed. When, however, the heating was carried further, until a dull red glow was produced, the substance was destroyed or so altered that it ceased to stimulate growth.

Again we have the suggestion that the growth stimulant is probably an organic substance rather than a mineral salt. Further than this it has not up to the present been possible to carry the matter. In addition to small quantites of many inorganic salts, traces of a number of organic substances have been tried, amongst them being asparagin, calcium succinate, calcium malate, theobromine, tyrosine, urea and uric acid, but in all cases the results were negative.

An observation recorded by my colleague Mr. L. R. Crawshay is of much interest in connection with this point. Mr. Crawshay was carrying out experiments in which he tried to keep alive in the Laboratory some Copepods belonging to the species *Calanus finmarchicus*, which he was feeding on the diatom *Nitzschia*. He found that in the vessels containing the animals the diatoms grew and multiplied rapidly. If, however, the diatoms were put into similar vessels in which no animals were present, and kept under precisely the same conditions, very much less growth took place. Here again it looks as if some substance excreted by the animals helped to produce a luxuriant growth of the plants. The analogy seems complete with what we are all familiar with on land, the beneficial effect of animal manure upon plant life. A particular interest, however, attaches to Crawshay's work, because he did not get the increased diatom growth with other species of Copepods which he tried, but only with *Calanus finmarchicus*.

The outstanding feature then of the experiments which I have been describing to you on the growth of marine plankton diatoms, is the essential importance for the vigorous growth of these plants of some specific substance which is present in exceedingly minute quantities in natural sea-water and without which energetic growth does not take place. This substance, which acts as a growth stimulant, is, we have reason to suspect, a somewhat stable organic compound produced by other living organisms.

And now perhaps you will pardon me if I appear to wander into subjects which may seem far removed from my immediate purpose, but I hope I may succeed in showing how intimately the most diverse branches of scientific enquiry are often interwoven one with the other, and what unexpected light may be thrown upon a problem by investigations which at first sight look very remote.

Much striking work has been done recently on the subject of animal nutrition. At Cambridge Dr. Hopkins has shown that young rats do not grow when fed on an artificial diet composed of pure protein, starch, cane sugar, lard and inorganic salts, although such a diet, which we might almost call an artificial milk, contains all the generally recognised constituents of a perfect food. If, however, quite a small quantity of natural milk is added to this artificial food the young rats thrive. A minute trace of some substance present in the natural milk makes all the difference between growth and no growth.

Amongst the natives in some parts of Eastern Asia a very troublesome disease known as beri-beri has been prevalent in recent years, and has caused considerable mortality. It has been shown that the disease is directly caused by a too exclusive diet of polished rice. In the process of polishing, the outer husk or skin of the rice is entirely removed, and with the removal of the husk some substance is taken away which is essential if the rice is to be a sufficient food. The disease is at once cured by putting the patients on a suitable mixed diet.

The disease is also produced in pigeons if they are fed entirely on polished rice, and some interesting results on the cure of birds suffering from it have been obtained by Drs. Cooper and Casmir Funk. These investigators were able to extract from rice polishings a definite chemical substance, an organic compound of a highly complex character, which when added in exceedingly minute quantities to the diet of polished rice very rapidly cured the birds of the disease. To this substance, which is present in minute quantites in the husk of the rice, they gave the name of *vitamine*. They were able to isolate the same curative substance or vitamine from yeast, from milk and from bran. Another instance of a similar character concerns us more nearly in this country. In the preparation of fine white flour, from which our ordinary white bread is made, the outer layers of the wheat are entirely removed. It appears, however, that in these outer layers there is an active principle which is of essential importance to the value of the wheat as food material. In experiments carried out by Dr. Leonard Hill it was found that young rats and mice would not live when fed exclusively on white flour and water, whilst those fed on wholemeal flour did much better. Pigeons fed on a diet consisting only of pure white bread all died, but if to the white bread was added an extract of bran and sharps, that is an extract of the outer husks of the grain, the pigeons lived quite healthily. Here again we have to do with minute traces of the so-called vitamines, which are essential to healthy nutrition. In an ordinary mixed diet, such as is usually adopted in this country, the use of white bread made from refined flour is probably not very harmful, as the small quantity of vitamine required will be obtained from other constituents of the food, such as milk or fresh vegetables. Amongst some of the poorer classes of the population, where white bread is often the principal food, there is a distinct danger of malnutrition, especially in growing children.

It seems probable that scurvy, a disease so dreaded by the deep-sea sailors of former days and one which has proved so disastrous to our Arctic and Antarctic explorers, is due to the absence from the diet of accessory substances similar in their nature to vitamines. These substances are present in minute quantities in lime juice, fresh vegetables and fruit, the addition of which to the diet has a curative effect on the disease.

A connection between the study of the growth of marine diatoms and the study of the cause and cure of cancer may at first sight seem remote, but some recent work in connection with that disease certainly suggests that the two studies may be mutually helpful. In cancer we have a rapid and uncontrolled growth of certain tissues, and the work of H. C. Ross and others is directed to show that this rapid growth is due to the production in the body of the patient of minute quantities of certain complex organic substances, which act as growth stimulants and bring about the rapid and abnormal proliferation of the tissue cells. These growth stimulants have been termed *auxetics*, and it is not improbable that they resemble in their action, if not in their chemical constitution, the vitamines which cure the disease of beri-beri and the potent substance occurring in natural sea-water, the merest trace of which is capable of producing a luxuriant growth of diatoms in an artificial solution, which in its absence is unable to sustain growth at all.

A still closer parallel to what occurs in the case of the diatom cultures has recently been brought to light in connection with agricultural research. I refer to the investigations of Prof. Bottomley, of King's College, London, on certain substances derived from Sphagnum peat. Sphagnum peat consists of the partly decayed remains of the Sphagnum moss, which occurs so commonly in moorland bogs, as for example in much of the bogland of Dartmoor. Prof. Bottomley found that when Sphagnum peat was subjected to the action of certain bacteria obtained from soil, a kind of fermentation took place which resulted in the formation of a substance which, when fed to growing plants, stimulated and accelerated their growth to a quite surprising extent. This substance was soluble in water and was effective in very small quantities. Prof. Bottomley states that "Dr. Rosenheim, of King's College, found that seedlings of *Primula malacoides* potted up in loam, leaf-mould and sand, and treated twice with a water extract of only two-tenths (0·18 grams) of a gram of bacterised peat, were after six weeks' growth, double the size of similar untreated plants, and it was noted that flower production and root development were promoted equally with increase of foliage."

By using methods similar to those which had been employed in separating vitamine from rice polishings, Bottomley was able to separate the active substance from the bacterised peat and to test its effect upon the growth of wheat seedlings. Some seedlings were allowed to grow in a solution containing only pure food salts (nitrates, phosphates, and so on), whilst others were grown in the same solution to which one part in three millions of the active substance from bacterised peat had been added. During the first fortnight both sets of seedlings grew at about the same pace. After that those to which no active substance had been fed began to dwindle, and at the end of fifty days their weight had actually diminished by 8·4 per cent. Those seedlings, on the other hand, which had received the one part in three millions of active substance from the bacterised peat, continued to grow and at the end of the fifty days their weight had increased by 55 per cent of the original weight.

Bottomley's observations are of great practical interest, since they seem to explain in an intelligible way the beneficial effect upon crops of farmyard and organic manures. It is not sufficient to add to the soil only artificial fertilizers, since without a supply of the necessary accessory organic substances, which act as growth stimulants, the crops are unable to make use of the food supply which these artificial fertilizers provide. The accessory substances are, however, produced in the minute quantities required when a certain proportion of organic manure is also employed.

But it is time for me to return to the conditions which prevail in the sea, although I hope that these digressions into animal nutrition, into the causes and cure of certain diseases, and into the treatment of agricultural crops have been of some service in throwing light upon the subject in hand. What is the source from which the sea obtains the food substances necessary for the growth of its plant life—the phosphates, nitrates and other inorganic salts and the organic substances of the nature of growth stimulants? There is clearly within the sea itself a continuous cycle of these plant foods, and we may to that extent regard the sea as a self-contained whole. The plant makes use of the food substances dissolved in the water and is then itself eaten by some animal. The animal, either directly as the product of its own vital activity or indirectly through the action of putrefying bacteria when it dies, returns the plant foods to the sea.

In addition, however, to this food cycle within the sea itself, there is another source of supply, the importance of which is probably very great, though up to the present it has not been studied with all the attention it deserves. This source of supply is the material carried into the sea by drainage from the land, the great bulk of it being, of course, brought down by the rivers. The subject has recently been discussed in an important memoir by Prof. Gran of Christiania. It has long been known that life in the sea is specially abundant in the neighbourhood of the coasts and in regions which are under the influence of currents containing a great admixture of river water. The study of the distribution of the plankton, or floating life of the sea, has helped greatly in throwing light upon this question. The quantity of plankton in coastal waters is very much greater than that found in the open ocean far from land. The proportion has been estimated at 50 : 1.

Prof. Gran maintains that this can only be explained by supposing that the coastal waters are richer in nutritive or food substances, and these nutritive substances must have been supplied by drainage from the land. It has been found that the development of the plankton, especially of the plant plankton, commences in the inshore or coastal waters and from thence spreads out gradually into the ocean. All the great fishing areas are found in regions where coastal water predominates and where the admixture of river water is large. The North Sea, the most productive area of the British fisheries, receives the waters of the Rhine, the Elbe, the Thames, and many other rivers. The great cod fisheries off the coast of Norway take place in waters which are derived in large part from the Baltic current. The Bristol Channel and Irish Sea are other examples upon a smaller scale.

On the other hand, over the vast areas of the open ocean far from the coasts, where the influence of land drainage is not felt and where the quantity of minute life in the water is small, no important fisheries are carried on. As far as we seem to understand the conditions of the problem at present, it does not appear likely that any great fisheries can be developed in these open waters. Just as the desert areas of the land, notwithstanding the abundant energy of sunlight which falls upon them, are unable to support vegetation from lack of water, so it seems these great ocean wastes fail in making use of the sun's power for the production of organic life from lack of substances which only the land can supply. If this be a true view of the case, when, as will probably happen sooner or later, the fisheries of the coastal banks have reached the maximum extent of their capacity, we shall have to look for any further increase of the supply of fish for food purposes to an extended practice of fish culture, a method at present confined almost entirely to fresh-water fishes. The extension of fish culture to marine fishes, which are much more delicate and difficult to rear than those which live in fresh-water, is by no means an easy matter, and much further knowledge will be necessary before successful results can be obtained. The researches which I have described to you to-night were commenced largely with a view to obtaining information about some of the fundamental problems upon which any scientific practice of fish culture would need to be based. The investigation has at the present time reached only an early stage, but the results obtained are unexpected and not without interest. There seems reason to hope that a further extension of the work may be of some practical importance.

For a more detailed account of the researches referred to in this address see:

Allen, E. J., and Nelson, E. W., *On the Artificial Culture of Marine Plankton Organisms*, Quart. Journ. Micr. Sci., Vol. 55, p. 361, 1910, and Journ. Mar. Biol. Assoc., VIII, p. 421, 1910.

Allen, E. J., *On the Culture of the Plankton Diatom Thalassiosira gravida Cleve, in Artificial Sea-water*, Journ. Mar. Biol. Assoc., X, p. 417, 1914.

The Age of Fishes and the Rate at which they Grow.

Being the Presidential Address delivered before the Devonshire Association for the Advancement of Science, Literature and Art at the Plymouth Meeting, 18th July, 1916.

By

E. J. Allen, D.Sc., F.R.S.
Director of the Plymouth Laboratory.

[Reprinted from the Transactions of the Devonshire Association.]

With Figures 1–9 in the Text.

At a time like the present, when the Empire we have inherited stands facing a crisis of its fate, when indeed the whole structure of civilization as we know it has seemed to sway, when that which generations of earnest thinkers have dreamt of as the progress of the race recoils before the forces it has itself unchained, it is difficult to restrain a feeling of incongruity in discussing any subject that has no obvious bearing on the greater problems of the hour. But I am convinced that we are following the right course in carrying on, with such help as remains available, the work of this Association, whose object is the advancement of Science, Literature and Art. In the short, swift cataracts of war, no less than in the gentler, steadier flow of peace, these matters of the mind have still their power.

In selecting a subject upon which to address you it has seemed to me best not to attempt to travel beyond the limits of that branch of Science with which my own studies have been chiefly concerned, and the science of Marine Biology is one which has special claims on a Devonshire Society. The work of Colonel Montagu at the beginning of the nineteenth century, which gave us the first descriptions of so many of our British marine animals, and by the acuteness and accuracy of its observations laid the foundation of future knowledge of their habits and life-histories, was practically all carried out in the Salcombe and Kingsbridge estuaries. Dr. Leach, the pioneer in the study of British Crustacea, was born at Hoe Gate House, within a few yards of Plymouth Hoe, and some of his collections still find a home in the museum of the Plymouth Athenæum. Philip Gosse studied the shore life of our Devonshire coast at Torquay and at Ilfracombe, and his book on those British Anemones, which he found in such profusion at both these spots, remains a classic. It was at Plymouth that Spence Bate first followed the remarkable transformations that occur in the development of the common crab of our shores, and it was here that he procured a large part of the material upon which was based the monograph on British Sessile-eyed Crustacea, which he wrote in collaboration with Westwood.

It was due to the wealth of marine life discovered by these and many other local naturalists, that when in 1884 an Association, chiefly under the influence of the biologists connected with the Universities of Oxford, Cambridge and London, was founded for the study of marine life and particularly for the study of marine fishes, the site of the first Laboratory was fixed at Plymouth. The researches which have been carried out at that Laboratory have fully confirmed the view that we possess off the Devon coast a fauna as extensive and as remarkable for the variety of its forms as is to be found anywhere in northern Europe.

The sea fisheries of Devonshire occupy also a unique position in the history of British Fisheries, for it was the trawl fishermen of Brixham who, gradually pressing eastwards, extended their industry to Dover, Ramsgate and Yarmouth, until finally at Grimsby and Hull they laid the foundations of that immense trade, which with the coming of the steam trawler has taken toll of the most distant waters, from Iceland and the White Sea in the north to the coast of Morocco in the south.

You will, I think, agree that it is fitting that I should here, in passing, pay a tribute to the sturdy character and indomitable courage of the men of our steam fishing fleets. The Brixham traditions have survived. Those of us who had known the men and had sailed with them in times of peace knew already something of their worth, but the cool daring and patient bravery of their work since the war began has surpassed all expectations. It is not too much to say that to them, as much as to any men, we owe the protection of our commerce from the ruthless warfare of mine and submarine.

It is now many years since the first attempts were made to apply scientific methods to the study of problems connected with sea-fisheries, and the subject has developed into what is almost a distinct department of marine biology. Were I to attempt to deal even with all the many branches of modern fishery research, it would be impossible within the limits of a single address to give more than a very superficial account of each of them. It will, I think, be more useful and offer a better prospect of securing your interest in the subject, if I confine myself to one limited question which has received in recent years a considerable amount of attention from fishery naturalists. The subject about which I propose to speak is that of the age of fishes and the rate at which they grow. It requires no elaborate argument to prove that the study of this matter is of the first importance if we are to give a rational account of the possible productiveness of a fishery, of the rate at which the fishery can be replenished, and of the intensity of fishing which may be prosecuted without endangering its future prospects as a means of profit to the fishermen and a source of food supply for the people.

To begin at the beginning, I need hardly remind you of the now well-known fact that the eggs of the majority of our marketable marine fishes are small, transparent, spherical bodies, which are buoyant and float freely in the sea. The fact that the eggs of a fish are of this character, which we describe as pelagic, was first discovered by G. O. Sars in Norway, in 1864, whose observations were made on the Cod. It was discovered independently in Cornwall in 1871, in the case of the Pilchard, by that enthusiastic fisherman-naturalist and acute observer, whose name will be well known to you, the late Matthias Dunn, of Mevagissey. The only important British sea-fish which is an exception to this rule of having pelagic eggs, apart from the skates and dogfishes, whose rate of growth I propose to leave out of consideration altogether, is the Herring, the spawn of which is deposited on the sea floor and attached to shells, stones and gravel.

The time occupied in the development of the eggs of different fishes, from the time they are spawned to the time of hatching, was shown by Dannevig (**5**) to be dependent upon the temperature of the water in which they float, the increase in the rate of development being in direct proportion to any increase of temperature.

The following table compiled by Dannevig shows the average number of days occupied in the development of the eggs of certain species of fish at different temperatures :-

Temperature in Centigrade	1	+3°	4°	5°	6°	8°	10°	12°	14°
Cod (*Gadus morrhua*) . .	42	23	20½	17½	15½	12¾	10½	9⅔	8½
Whiting (*Gadus merlangus*) . .	—	—	—	15⅓	13½	10¼	8	6½	5¾
Haddock (*Gadus æglefinus*) . .	42	23	20½	17¾	15½	13	10¾	9⅔	8¾
Plaice (*Pleuronectes platessa*) .	–	—	—	—	18¼	14⅓	12	10½	—
Flounder (*Pl. flesus*) . . .	—	—	—	—	6½	5½	4½	3⅔	—

Time of incubation in days (24 *hours*).

These results have since been confirmed by Johansen and Krogh (**16**), working with more elaborate and accurate apparatus, and they have illustrated the relation between temperature and growth rate shown by Dannevig's figures by means of a graph,[1] in which the loci of the different observations for each kind of fish lie very nearly in a straight line, which means that the increase in rate of development, over the range of temperature examined, is directly proportional to the increase in temperature.

---

[1] The address was illustrated by lantern slides and the graph was shown.

It follows, therefore, that the actual time, under natural conditions in the sea, which an egg takes to develop, from the time it is spawned until it is hatched, is by no means constant. There are, I believe, no actual observations on the point and direct evidence as to the time occupied would not be easy to get. If we suppose that temperature is the only factor that need be considered, it is possible to deduce from the data given by the laboratory experiments the time taken in particular instances. Thus, in the waters off Plymouth, Plaice spawn from December to March. Taking the temperature at 9° C., which is the mean for February, the coldest of the four months, the Plaice egg would, according to Dannevig's figures,[1] take thirteen days to hatch. In the southern part of the North Sea, on the other hand, which is a great spawning-ground for Plaice, the mean temperature for February is 7° C., at which temperature the eggs would take about sixteen days to hatch.

When they first emerge from the egg, the young fishes are small, transparent larvæ, whose form is very different from that of the adult fish, and the next points to consider are the time occupied by the period of transition from the larval to the adult form and the increase in size which accompanies this change of form.

In treating of this period of the life-history we will consider separately the ordinary round fishes such as Cod, Whiting, Mackerel and Herring, and flat-fishes like the Plaice, the Sole and the Turbot. In the case of the round fishes it is a little difficult to draw a sharp line of demarcation between the end of the larval and the commencement of the adult life, since both as regards structure of body and habits of life the one passes very gradually into the other.

The time occupied by the larval period may be illustrated by one or two examples. The principal spawning time of the *Cod* in the North Sea begins in January and is at its height in February and March. The larvæ when first hatched have a length of about 4 mm., the length after absorption of the yolk being 4·5 mm. At a length of 25 mm. the adult form has practically been reached. Little cod of this size begin to appear, often hiding under the bell of a jelly-fish, from the middle of May onwards, that is to say about four months after the beginning of the spawning in January. We may say therefore with some confidence that these small cod of 25 mm. or 1 inch in length are from three to four months old.

Some observations on larval mackerel taken off Plymouth in the summer of 1914 will illustrate the method, a somewhat laborious one, it

[1] Cf. Apstein (**1**, p. 366). According to Apstein's figures the time would be nearer fourteen days at 9° C. and seventeen days at 7° C.

is true, by means of which the rate of growth of these young stages may be investigated. During May, June and July a large net of fine mesh the Petersen young-fish trawl—was used at frequent intervals, chiefly between Whitsand Bay and the Eddystone, for the purpose of collecting young stages of fish. Young Mackerel first appeared on the 25th of May and they continued to be caught fairly regularly until the end of June, whilst in July only three specimens of these early stages were found during the whole month. All the specimens captured were preserved and subsequently measured. The numbers taken at any one time were small, thirty-two being the largest number in a single haul of the net, but if we combine the figures obtained from the different hauls into two groups, certain interesting features appear. The following diagram represents the figures in a graphic form, the measurements being in millimetres[1] and each fish being represented by a dot :—

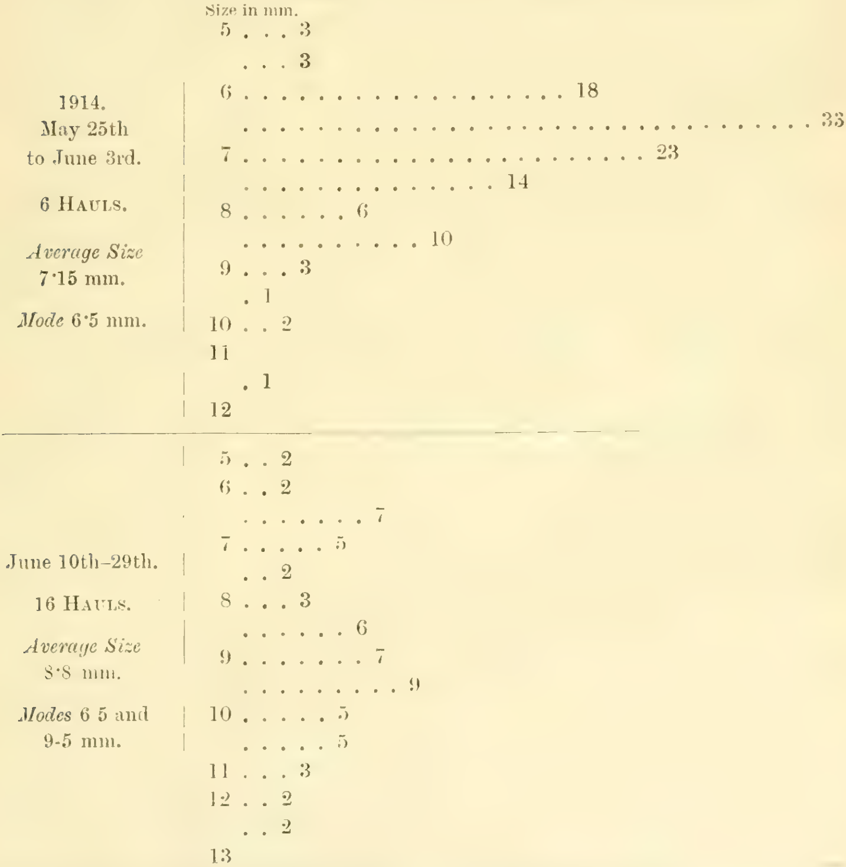


Fig. 1.—Larval Mackerel.

[1] A table showing the relation between British and Metric measures will be found on p. 424.

In the first group of hauls, which we may call the end of May group, the size of greatest frequency is 6·5 mm. and the numbers form a fairly regular curve about this mode, the average size of all the measurements being 7·15 mm. In the second group of hauls, the middle of June group, the numbers range themselves round two centres of frequency or modes, one at 6·5 mm., the other at 9·5 mm. Although the numbers are not perhaps sufficiently large to be conclusive, they at least suggest that these 9·5 mm. fish belong to the same batch of larvæ as the 6·5 mm. fish of the end of May group, whilst the smaller fish represent a new batch of young, derived presumably from another shoal of spawning Mackerel. If this be so, we should, I think, be not far wrong in concluding that a growth of 3 mm. took place in the three weeks' interval from the middle of the period May 25th to June 3rd and the middle of the period June 10th to June 29th.

I give this actual instance from our own observations merely as an illustration of the way in which the problem of the rate of growth of larvæ in the sea under natural conditions may be attacked. To arrive at perfectly certain and definite results a much larger number of specimens would be necessary, and confirmation in different years would be required.

The Cod and the Mackerel, whose larval growth we have just been considering, are typical instances of ordinary round fishes. We will now look for a moment at the flat-fishes in which a distinct and rapid change both in structure and habit of life takes place at the end of the larval period. The young fish abandons its pelagic existence, during which it swam freely through the mass of the water snapping here and there at the small floating creatures upon which it feeds, and takes to lying on its side on the sand at the bottom, feeding on small worms, shell-fish and crustaceans which the sand contains. This change of habit is accompanied by a twisting of the whole structure of the skull, in such a way that both eyes come to lie near together on one side of the fish,—on the coloured side which is uppermost as the fish rests upon the sand.

[A series of slides showing the metamorphosis of a flat-fish was shown.]

This change in structure and habit gives us a fixed point in the life-history of the fish, and for the purpose in hand we require to know for what length of time the free-swimming larval stage is continued, from the time that the larva leaves the egg until it settles down as a little flat-fish adapted to life on the sand. Unfortunately the evidence available is not sufficiently detailed to enable us to fix this time with the degree of accuracy which we should desire, though an approximate estimate of its duration can be made for certain species. For instance, the Plaice in the southern part of the North Sea commences to spawn in January;

spawning is at its height in February and continues into March. The youngest bottom stages of the Plaice, immediately after the transformation, are found in quite shallow water along the margins of sandy bays and are often taken by shrimpers, working with push nets on the shore. According to the researches of Dutch naturalists (Redeke, **20**, p. 40) these small Plaice appear at the beginning of April on the Dutch coast and they become numerous in May. If, therefore, we allow two to three weeks for the eggs to hatch, we are left with about ten weeks for the larval stages. It must be admitted that this is a very indefinite statement, but it is, I think, as near as we can get on the evidence at present available. The times will doubtless vary considerably in different localities and also in different years, owing to differences of temperature and of the food-supply available.

In the case of the Sole, which was reared by Fabre-Domergue and Biétrix (**6**) in the laboratory at Concarneau, the pelagic larval stage lasted about seven weeks, but this of course does not give us a reliable figure for the time taken under natural conditions in the sea.

The length at which the transformation is complete and the bottom life commences is in the case of the Plaice from 14–15 mm., for the Sole it is 10–11 mm. The sizes at the time of hatching are 6–7·5 mm. for Plaice, 3·2 mm. for the Sole.

We may say in general, then, that the adult characters in most fishes are established at the end of about three months from the time of spawning, and when the length is from a quarter to half an inch.

In order to determine the rate of growth subsequent to this period various methods have been employed and for some years past considerable attention has been given to the subject. It is possible, of course, to study the matter directly by keeping fishes in confinement and measuring them from time to time. But we can get little really valuable information in that way, as it is soon seen that the rate of growth depends very largely on the conditions in which the fish are placed, on the volume of fresh seawater supplied to the tanks, on the temperature of the water, and on the amount and nature of the food which is supplied. This is an interesting study in itself, and from some points of view may prove to be of practical importance, but it really tells us little or nothing as to the rate at which the fishes grow under natural conditions in the sea, which is the point of main importance.

Dr. Petersen of Copenhagen was the first naturalist to place the study of the subject on a sound scientific basis (Petersen, **19**) and the method he employed is still perhaps the most useful for dealing with the first one or two years of a fish's life. It consists simply in making a large and representative collection of the fish to be studied, from a particular locality and as nearly as possible at the same time, measuring the length of each individual fish and then plotting the measurements in the form of a graph or curve.

The following curve [cf. Hjort and Petersen (**11**), Plate IV] in which 8046 Cod,[1] caught off the East Coast of Iceland in July, 1904, are graphically represented (Fig. 2), illustrates the method. Each fish was measured and the numbers found at each centimetre are plotted. It will be seen at once that the fish group themselves around certain definite lengths. The smallest sized fish in the collection was 3 cm. long, and of this size there were 6 fish. At 4 cm. there were 65, and at 5 cm. 189. The numbers then begin to fall, there being only 43 at 6 cm., 8 at 7 cm., and but one fish at 8 cm. Then they rise again until another maximum occurs at 12 cm., with 139 fish. At 17 cm. the number has fallen to 12, after which another rise occurs until at 22 cm. we have 107. In this way the fish fall naturally into the six groups O–V. This division into size groups is due to the fact that the spawning season of the Cod in each year is a limited one, extending over only two or three months at the beginning of the year—January, February and perhaps March. By July the fish born at that time will have reached about 5 cm. in length. The next maximum at 12 cm. represents the fishes born the year previously, and the difference between 12 cm. and 5 cm., i.e. 7 cm., expresses the growth in length during the year. Then at 22 cm. we have the fish which have completed two full years, these fish in July when the samples were taken being two and a half years old.

Since all the fish were caught in 1904 we are able to say in what year each group was born, the V group, with a maximum frequency at 88 cm., being Cod born in 1899.

Now, although this method is satisfactory for the early years, the distinction between the groups becomes much less marked as the fish grow older, until finally the different year-groups run into one another and become indistinguishable. Fortunately, however, other methods have been discovered which enable us to attack the problem of age and rate of growth with even greater precision.

In the year 1898 Hoffbauer (**13**) published a paper in which he showed that the age of a fresh-water carp could be determined by an examination of the markings on the scale. In 1902 Stuart Thompson (**22**) published an account of some work carried out at the Plymouth Marine Laboratory in which he showed, for the first time, that a similar method was applicable to sea-fisheries, his researches having been made upon fishes of the Cod family—the Gadidæ—especially on Whiting and Pollock.

---

[1] The number of fish at 45 cm. has been taken at forty-seven instead of ninety-seven given by Hjort, which appears to be a misprint. Forty-seven agrees with what is shown in the graph and is in accordance with expectation.

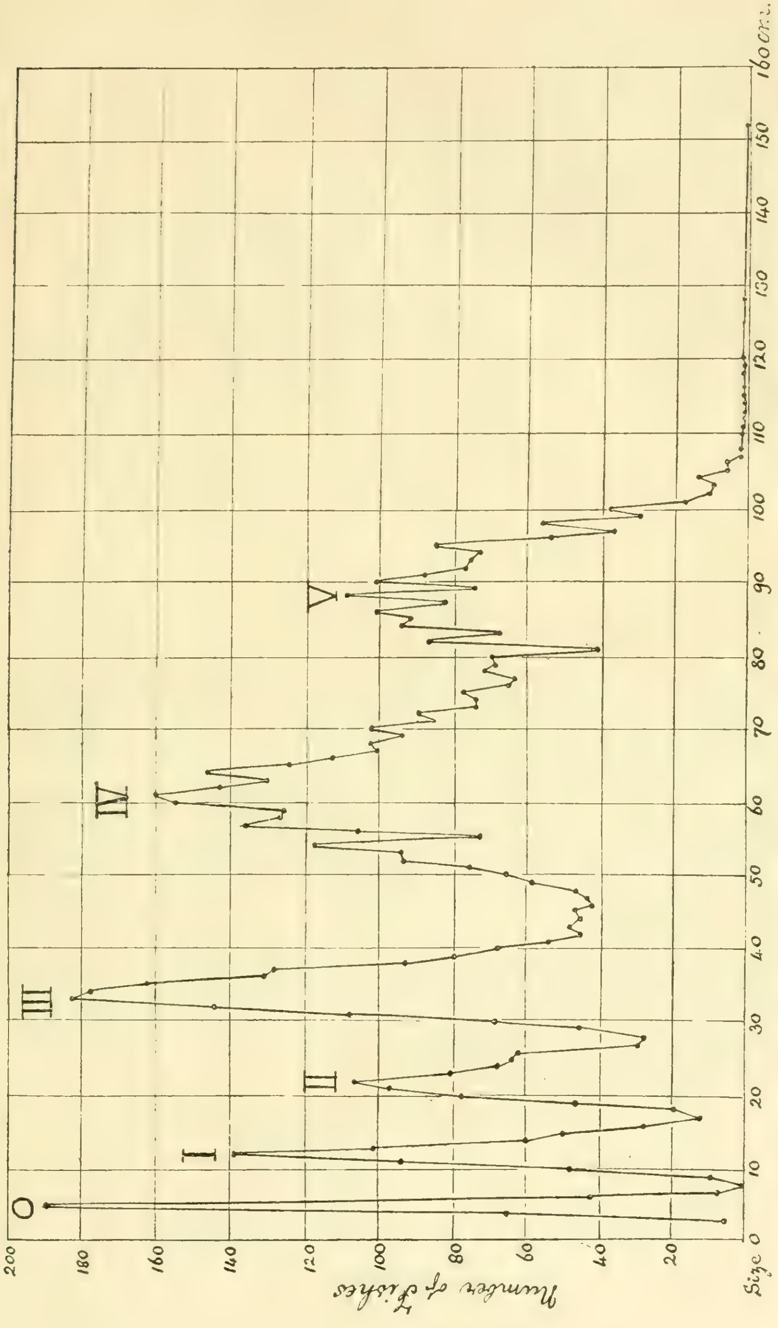


FIG. 2.—Curve showing the distribution according to size of 8046 Cod caught off the East Coast of Iceland, in July, 1904. (After Hjort and Petersen.)

Fig. 3 is from a drawing of the scale of a coal-fish (*Gadus virens*). The surface of the scale appears covered with a series of concentric rings or ridges. When growth is proceeding rapidly there is a considerable space between succeeding ridges, when growth becomes slow the ridges crowd closely together. But the fish grows most rapidly during the summer months, when the water is warm and food is plentiful, whereas during the winter growth becomes slower and slower, and even ceases altogether. It is during this winter period of very slow growth that the concentric ridges on the scale become crowded together and give the appearance of a darker ring on the surface of the scale. On the scale figured there are two such winter rings and the growth of the third summer is well advanced.

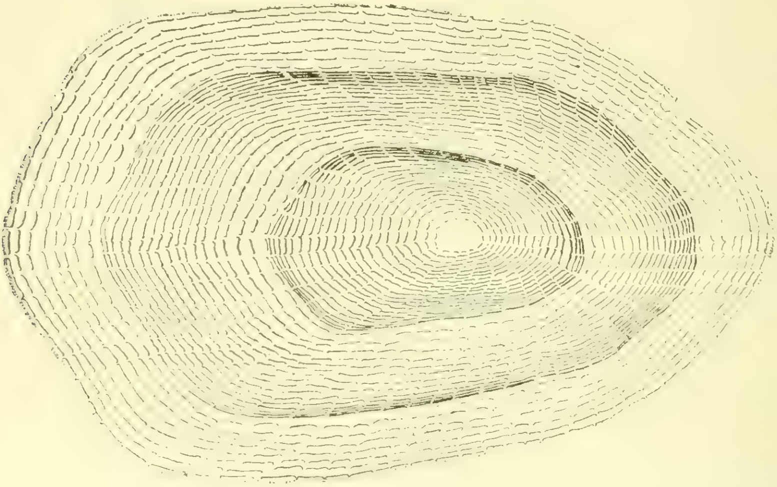


FIG. 3.—Scale of Coal-fish (*Gadus virens*). (After Damas.)

That this explanation of the appearance presented by the scale is the correct one has been proved by the examination of scales taken from fish caught at different times of the year. A fish captured in summer, such as the one illustrated, has the ridges far apart at the margin of the scale, whilst in fishes captured as the season advances towards winter the ridges round the margin become crowded together.

In the case of the Cod family these markings on the scale are especially distinct and the examination of a few scales is generally sufficient to fix the age (Winge, **25**). The number of winter rings formed by the crowding together of the ridges tell us at once the number of years of life which the fish has completed. It must be remarked, however, that the appearance of these winter rings is not in the case of each individual fish as clear and definite as that shown by the scale illustrated, and in a large batch of fish a certain number will be doubtful and the exact age a little uncertain.

By examining large samples these exceptional instances cease to have any importance, as they are not sufficiently numerous to alter the average values obtained.

The Salmon is one of the fish the age of which is often well shown on the scale, and a good deal of work has been done upon it (Masterman, **18**). The Herring is another case which I shall consider in more detail presently.

In certain other fishes, as for example the Plaice, the scales, although they show indications of similar winter rings, are not marked sufficiently clearly to make them easily available for age determination. Fortunately, however, other structures of the fish have been found which show in a very definite way alternating rings expressing different rates of growth, which enable us to estimate age with great accuracy. These structures are (1) the otoliths or ear-stones, and (2) certain of the bones of the fish. In the Plaice, the fish to which this method has been chiefly applied, the age of the younger fishes up to about six or seven years old is best seen on the otolith, that of older ones on the bones.

The otoliths or ear-stones (Fig. 4) are small, oval, calcareous bodies which lie in the cavity of the inner ear. They can be removed easily for examination from the dead fish by making a single incision in the head in an appropriate direction, and an inspection with a simple lens generally suffices to make an age determination (cf. Reibisch, **21**).

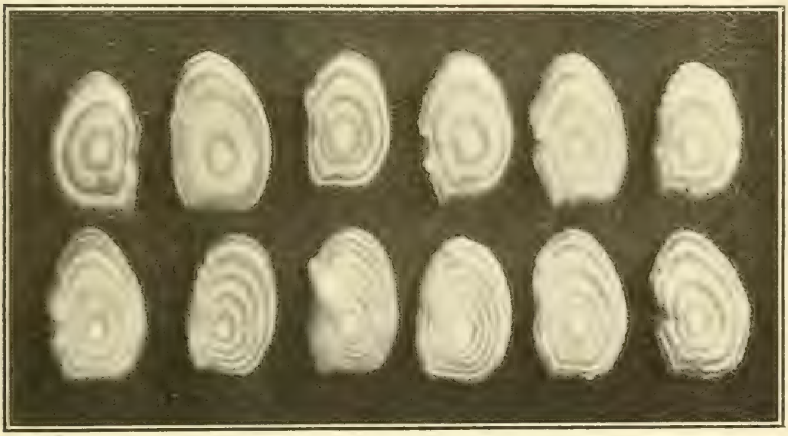


Fig. 4.—Otoliths of mature male Plaice. Upper row—Otoliths of Plaice from the West Bay (English Channel). Lower row—Otoliths of Plaice taken in the southern deep water of the North Sea, near the Gabbard Light Vessel. (After Wallace.)

As will be seen from the figure, alternate white and dark rings are seen, when the otolith is examined by reflected light. The white rings are formed in spring and early summer, the dark rings in late summer and autumn. During the winter practically no growth of the otolith takes place. The first white ring is formed in the spring following the year of birth, that is when the fish is just one year old, and the total number of white rings will therefore give us the number of years of life which the fish has completed.

As the Plaice gets older, however, the rings at the edges of the otoliths are so crowded together that it becomes impossible to count them. For these older fishes Heincke (**9**) has shown that an examination of the bones, after special treatment, gives the information required.

It is clear that if we can determine the age of individual fishes, and if we do this on sufficiently large samples, we at once obtain some information as to their rate of growth, for if, say, the average size of the two-year-old Plaice in a particular locality is 20 cm. and the average size of the three-year-olds is 25 cm. we shall not be far wrong in concluding that a Plaice of 20 cm. will grow about 5 cm. during the next year of its life. This conclusion, however, assumes that the conditions of growth are the same each year, and from information now available we know that this is not always true, but that some years are more favourable for growth than others. Growth in different localities, also, even though they may not be very distant from each other, may differ greatly. What we can obtain by the use of the methods already described, if the observations are repeated for a number of years, is the *average* rate of growth for each year of age.

There are, however, other methods by means of which we can get an idea of the actual rate of growth in a particular area at a particular time. The one which has been most used and has yielded the most reliable results is the method of marking experiments. In these experiments a healthy fish is measured soon after being caught and a small metal label is attached to it, generally at the base of the dorsal fin. The label is numbered and the fish is returned to the sea. When it is subsequently caught again by the fishermen it can be identified by its number and measured a second time. The actual amount of growth will then be known. A great many experiments of this kind have been made on both Plaice and Cod, and large numbers of the fish have been caught and returned by the fishermen to the various laboratories. Even these experiments, however, which were carried out primarily to give information as to the migrations of the fish, are subject to at least one possibility of error, owing to the fact that the future growth of a fish may be considerably retarded by any slight injury it may have sustained when it was first caught. This source of error has to some extent been overcome by keeping the fish in tanks of running sea-water for some time before they are measured and marked, and only using such fish as appear to be quite uninjured and full of vigour.

We must now pass on to consider some of the conclusions which have resulted from the use of these methods of investigating age and growth rate. In the case of the Plaice, the researches of Dr. Wallace, which were carried out at the Lowestoft Laboratory of the Marine Biological Association, are amongst the most important. The method he employed was the study of the otoliths, his results being based on a total of 20,000 fish, each of which was measured and its age determined. In addition to this Wallace makes use of the records of the otoliths of another 20,000 measured Plaice collected by the Board of Agriculture and Fisheries (**24**). These numbers will give some idea of the extent of the investigations which have been made.

The following table embodies the result of the analysis as regards age of two series of samples of Plaice trawled by Wallace along a line nearly at right angles to the Dutch coast, from Texel to the Leman Banks, commencing about three miles from the shore and running out some eighty or ninety miles into the North Sea. The samples were taken in May and September, 1905. (Wallace, **23**, Rep. II, Pt. I, p. 26.)

1. Males.

The	I group	averaged	9·4 cm.	in May and	14·9 cm.	in Sept.
,,	II	,,	16·2 cm.	,,	19·9 cm.	,,
,,	III	,,	22·2 cm.	,,	25·4 cm.	,,
,,	IV	,,	27·2 cm.	,,	29·3 cm.	,,
,,	V	,,	31·6 cm.	,,	33·7 cm.	,,
,,	VI	,,	34·8 cm.	,,	34·5 cm.	,,

2. Females.

The	I group	averaged	10·3 cm.	in May and	15·2 cm.	in Sept.
,,	II	,,	16·8 cm.	,,	20·9 cm.	,,
,,	III	,,	23·6 cm.	,,	25·8 cm.	,,
,,	IV	,,	28·3 cm.	,,	30·9 cm.	,,
,,	V	,,	34·3 cm.	,,	37·7 cm.	,,
,,	VI	,,	38·5 cm.	,,	41·3 cm.	,,

[A number of diagrams were also shown illustrating Wallace's results.]

The samples of fish from which these figures were derived were taken, as already stated, upon a line extending from the Dutch coast seawards to a distance of eighty or ninety miles. Wallace was the first to point out that if we are to obtain really accurate values for the average size of the Plaice belonging to any particular age-group in a given locality, we can only do so by collecting samples uniformly in this way at different distances from the shore. In order to make it clear why this is so, it will be necessary to give a short account of the distribution of the Plaice according to size, and for this purpose we will consider its distribution in the North Sea.

When we were dealing with the larval stages of the Plaice, you will recollect that we left the earliest bottom stages inhabiting the margins of the sandy shores in quite shallow water. During the first year of their life the young Plaice remain close to the shore in depths under ten fathoms. As they grow larger they move further and further seawards away from these nursery grounds, and in the North Sea it may be taken as a general rule that the average size of the Plaice becomes larger the further out into the open sea we get.

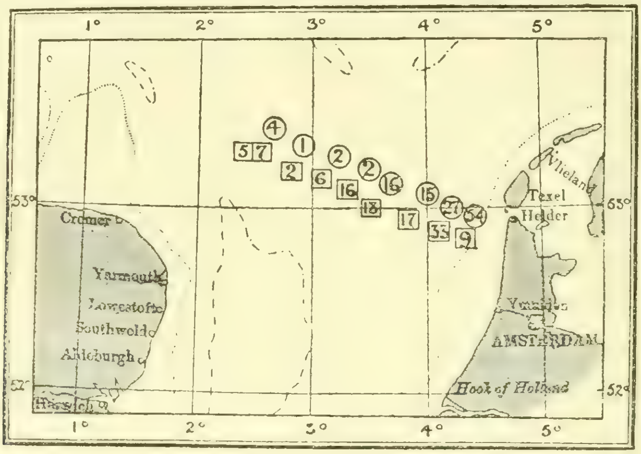


FIG. 5.—Plaice. Catch per hour of the III Group. (After Wallace.)
○ = May, 1906 (Covered Beam Trawl).
□ = September, 1905 (Otter Trawl).

This is well illustrated by the charts published by Garstang (8) showing the distribution of Plaice in the North Sea according to average size.

This seaward movement, it is important to note, depends upon the size of the fish rather than upon their age, so that the larger individuals of any year class are found further out to sea than the smaller ones. If we now look at the next Chart by Wallace (Fig. 5), which illustrates the catch per hour of Plaice of the III Group, that is fish between three and four years old, on the line running out from the Dutch coast—from Texel to the Leman Bank—we shall see that this group is taken along the whole line. It is most abundant near the coast, where the average size of the fish is small, and the numbers captured gradually diminish as we move seawards, the size of the fish at the same time becoming larger. The chart also shows that between May (represented by the circles) and

September (the squares) there has been a distinct shifting of the group of fish seawards as they have grown larger.

It will be clear, therefore, that if the fish are distributed in this way according to size, we must take uniform samples all along the line in order to obtain the true average of those belonging to any age-group. If, for instance, in the case of this III Group we took samples only near the coast we should miss all the larger fish belonging to the group, whereas if we took samples only at the seaward end of the line we should miss all the small ones. In the latter case our average would be far too high, in the former case it would be far too low. Wallace therefore is quite justified in maintaining that samples of Plaice for age determination must be taken upon such radial lines, if accurate average sizes for the different years of age are to be obtained.

One of the points which has come out most clearly in the course of these studies is the great differences in rate of growth which are found, firstly at different seasons of the year, secondly in different years, and thirdly in different localities.

As regards seasonal differences we may say that in the North Sea the year's growth begins in the spring, about the month of April; it goes on vigorously during the summer until September, slows down in October, and from that time until the following April there is practically no growth at all, at any rate in the shallow water near the coasts. In the central portions of the North Sea, for example on the Dogger Bank, a certain amount of growth does seem to take place in the winter.

The evidence for differences in the rate of growth of Plaice in different years is chiefly based on the work of the Danish naturalist Johansen (**14**), who has studied the question by means of marking experiments carried out off the North Sea coast of Denmark. Thus the average annual growth for specimens of 20 to 29 cm. liberated in the Horn Reef area in 1903 was only about 4 cm., whilst in 1904, 1905, 1906 and 1907 it was from 6 to 7·5 cm. In this connection Johansen notes the interesting fact that in 1903, when the growth was abnormally low, there was an unusually rich stock of under-sized fish on the Horn Reef grounds, which suggests that the rate of growth may depend, amongst other things, upon the density of the Plaice population (Johansen, **14**, III, p. 37).

It is possible, therefore, that a certain amount of fishing on grounds overcrowded with young fish may tend to increase the rate of growth of the fish that remain.

That the rate of growth of Plaice differs widely in different localities may be inferred from the fact that the average length of the different age-groups is different in different areas, provided always that the samples on which the figures are based are adequately distributed or at least properly comparable. Thus Wallace's samples show that Plaice of the II Group in August, that is fish two and a half years old, average 6 cm. longer in Tor Bay on the South Devon Coast than those in deeper water on the Leman Banks in the North Sea, and 11 cm. longer than those from the shallow water off the coast of Lincolnshire, the Devon fish being thus from one to two full years ahead of those from the North Sea.

This rapid growth of the Devon fish is clearly reflected in the structure of the otolith, as will be seen from Fig. 4. The broad white rings are in marked contrast to the narrow rings of the North Sea fish (Wallace, **23**, Rep. III, p. 142A, Figs. 6 and 7).

The following table (p. 415) summarizes Wallace's results as to the average size of Plaice of the different age-groups in different localities.

From this table it is possible also to compare the difference in rate of growth of males and females. It will be seen that on the whole females grow more rapidly than males, and that this difference tends to increase as the fish grow older.

The great differences which may occur in the rate of growth of Plaice on different grounds are strikingly shown by the results of the transplantation experiments carried out by Garstang and Borley in the North Sea [Garstang (**7**), Borley (**2**), Lee and Atkinson (**17**)]. Small Plaice caught on the shallow young-fish nurseries off the Danish and Dutch coasts were carried in sea-water tanks to the Dogger Bank, which lies in the middle of the North Sea. They were then measured, marked with

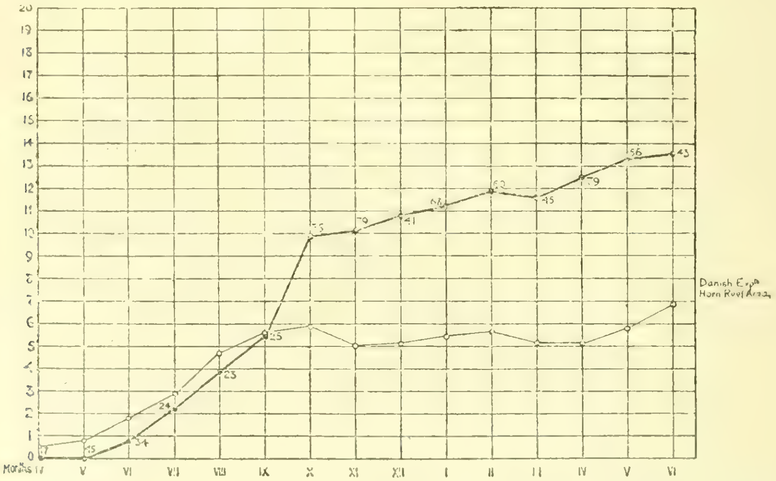


FIG. 6.—Showing growth of fish transplanted to the Dogger Bank in the combined experiments of the years 1904–8 compared with that shown by the Danish marking experiments in the Horn Reef area in the years 1903–5. (After Borley.)

AVERAGE SIZES OF THE PRINCIPAL AGE GROUPS OF PLAICE FROM DIFFERENT FISHING GROUNDS.

From Wallace [**23**], Report III, Tables 11 to 16, pp. 136–141. Length in centimetres.

Age Groups.	Males.						Females.						
	I	II	III	IV	V	VI	I	II	III	IV	V	VI	VII
Texel to Leman Banks. September, 1905. 7–17 fms.	14·9	20·0	25·4	29·3	—	—	15·1	20·9	25·8	30·9	—	—	—
Texel to Leman Banks. May, 1906. 13–17 fms.	—	14·6	21·3	27·3	30·9	—	—	14·9	22·5	28·8	32·9	—	—
Scheveningen and Southern Deep Water. May, 1906. 12–23 fms.	—	16·5	21·9	27·7	31·1	—	—	17·7	22·7	29·1	32·1	—	—
South Dogger and Flamboro' Off. Winter (Oct.–March)	—	—	29·1	34·1	37·0	38·1	—	—	30·4	36·6	41·0	44·1	47·5
Great West Bay (English Channel). Winter (Nov.–Feb.). 3–7 fms., 17–30 fms.	20·3	27·1	31·0	32·9	—	—	20·4	28·3	31·8	35·5	—	—	—
Tor Bay and Start Bay. August, 1909. 3–8 fms.	18·3	27·9	31·3	—	—	—	18·4	27·7	33·5	37·4	41·3	—	—

numbered labels and liberated. The transplantation was carried out in May, and during the following year large numbers of the marked fishes were returned by the fishermen. The amount of growth shown by the following autumn and winter was very remarkable. Small, under-sized fish of little or no market value had become fine Plaice, of good size and in excellent condition. The preceding diagram (Fig. 6) shows the growth of these transplanted fish, compared with the growth of fish of the same size which had remained on the inshore grounds. Taking the figures for, say, the following January, whereas the average length of the transplanted fish was 11 cm. the size of those left on the Horn Reef ground was about 5·5 cm.

If instead of considering the length of the fish we take the percentage increase of weight the result is even more striking. Whereas by the following spring the fish that remained on the Danish Horn Reef ground had increased in weight by 100 per cent., that is to say, had doubled their weight, those put out on the Dogger had increased their weight by 400 per cent., that is to say, they were five times as heavy as they were originally.

Since well-grown Plaice command a much higher price per lb. than small ones this increase of weight means that the value has increased to perhaps seven times the original value.

These results of investigations on the age of Plaice and their rate of growth have several important practical aspects, apart from the suggestion of a direct improvement of the fishery by the transplantation of young fish from crowded nursery grounds to rich feeding grounds such as the Dogger Bank, where the rate of growth is much more rapid. It would seem that the most profitable fishery would result from concentrating the fishing as much as possible on Plaice of the Age Groups IV, V and VI, that is to say, on fish in the fifth, sixth and seventh years of their life. Before this they are small, but capable of rapid growth and rapid increase in value. After the seventh year the growth gets slower, and as long as a sufficient supply of mature fish is allowed to remain to ensure an adequate amount of spawn for the perpetuation of the race, it would appear that from a commercial point of view it is of greater advantage to put the seven year olds on the market rather than to allow them to remain in the sea. They would increase in value very little compared with the amount of nourishment they would consume, whilst when they are removed the food they would have eaten becomes available for the younger fishes, which grow in size and value at a much more rapid rate.

In this connection the *age* at which the majority of Plaice mature for the first time is important. According to Wallace (**24**, p. 40) for female Plaice this "age of first maturity" in the Southern North Sea is five years, in the middle North Sea six years, and further north seven years. In the English Channel, on the other hand, the bulk of the females reach maturity at *four* years of age. The average age for the males may be a year earlier than for the females.

We have now perhaps devoted sufficient attention to the Plaice, and will pass on to consider certain investigations into the age of the Herring, which bring out very clearly another application of a knowledge of the age of fishes, which may have an important practical bearing. These investigations we owe especially to the energy and enterprise of Norwegian naturalists under the leadership of Dr. Johan Hjort.

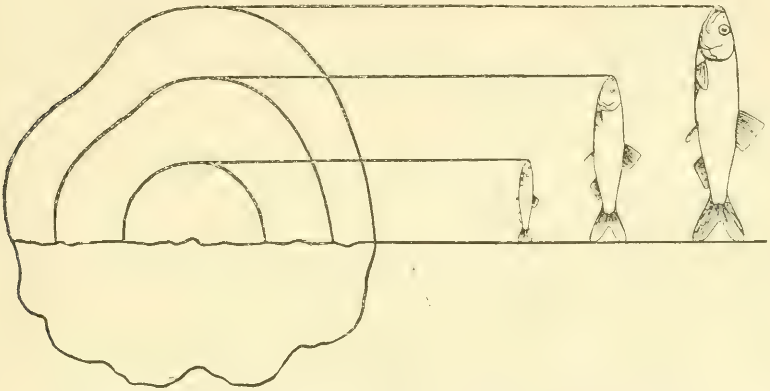


FIG. 7.—Growth zones of herring scales compared with size of fish. (After Hjort.)

As with most marine fishes, the growth of the Herring comes practically to a standstill during the winter. This winter rest is clearly indicated by a ring-like mark on the surface of the scale, these rings being often very definite and precise.

That each ring really does represent the cessation of growth during the winter has been proved by Lea, by examining samples of Herrings month by month during the year (**12**), in the same way as was done by Wallace with the otoliths of the Plaice. It was possible to follow the band of summer growth becoming wider and wider, until as winter came on it ceased, and the darker ring was found at the margin of the scales. This being so it is obvious that an examination of the scale can tell us a good deal more about a fish's history than merely its age. We can indeed infer the length of the fish at the end of any particular year of its life, for it has been possible to show that the length of the fish is always proportional to the length of a particular scale. If, therefore, we magnify the scale until its total length from the median transverse line to the edge is equal to the length of the fish, the distance from this line to each of the winter rings will be the length which the fish had at the time the ring was formed. This will be clear from the diagram Fig. 7.

Fig. 8 illustrates the composition of three samples of Norwegian Spring Herring taken in March, 1907, and analysed by Dahl (**3**), by an examination of the scales, into age groups. It will be seen that the majority of the fish belong to the IV, V, VI, VII and VIII year-classes, the best-represented class being IV. The position of the apex of each curve gives us the size of fish most frequently found in each age group.

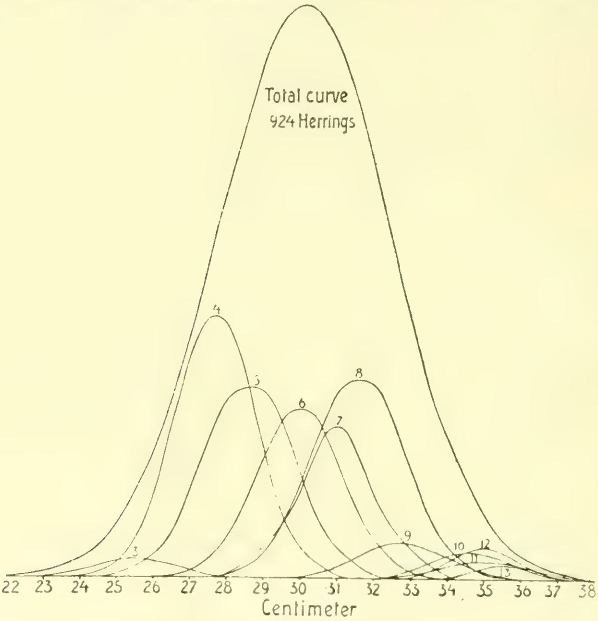


FIG. 8.—Analysis of three samples of Norwegian Spring Herring taken in March, 1907, into age groups. (After Dahl.)

Samples of Norwegian Spring Herring have been examined in this way every year since 1907 and the results obtained are given in the following table (p. 419), the number of fish belonging to each year-class being expressed as a percentage of the whole sample (Hjort, **12**, p. 219, Table I).

An examination of the figures in this table reveals a very remarkable fact. If we commence with the year 1908, we see that 34·8 per cent. of the fish belong to the year-class IV, that is to say, they are fish which were born in the year 1904. We see further that no other year-class is nearly as well represented, the next in order being the IX year-class, of which the sample contains 14·4 per cent. Now look at the percentages for the year 1909; the best represented class is the V year-class, with 43·7 per cent. But in 1909 the V year-class is composed of fish born in

AGE OF NORWEGIAN SPRING HERRING IN THE YEARS 1907–1914.

THE REPRESENTATION OF EACH YEAR-CLASS IS GIVEN IN PERCENTAGES.

YEAR-CLASSES	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1907	**1·6**	22·2	18·5	14·8	12·6	19·4	3·4	2·3	1·7	2·2	0·9	0·5	—	—	—	—
1908	—	**34·8**	12·2	11·6	11·1	8·5	14·4	1·9	1·1	1·5	1·5	0·6	0·3	0·1	0·1	—
1909	—	0·4	**43·7**	11·9	4·1	4·8	6·7	17·6	3·3	2·6	1·6	2·3	0·4	0·2	0·4	0·2
1910	—	1·2	9·9	**77·3**	6·7	1·0	0·4	1·1	2·0	—	—	—	—	—	—	—
1911	—	0·6	4·1	17·3	**70·0**	5·5	1·5	0·6	0·5	0·1	—	—	—	—	—	—
1912	—	1·6	3·1	3·9	14·5	**64·3**	6·4	1·6	1·2	1·2	1·5	0·6	0·1	—	0·1	—
1913	0·1	0·7	2·2	3·4	4·8	13·3	**64·7**	5·1	1·2	1·2	0·5	0·2	0·2	—	—	—
1914	—	0·6	3·3	6·9	5·2	7·2	13·9	**54·3**	5·0	1·5	1·2	0·4	0·5	—	—	—

1904. In 1910 the VI year-class, with 77·3 per cent., completely dominates the others ; still the fish born in 1904. In 1911 the VII year-class, in 1912 the VIII year-class, and in 1913 the IX year-class still form from 64 to 70 per cent. of the whole population, the fish in each case being those born in 1904. In 1914 these fish still form 54·3 per cent. of the whole. Thus it will be seen that for six or seven years this one year-class of 1904 dominates the fishery. If we look at the figures still more closely we shall see further evidence that a particular year-class may be of special importance over a series of years. In 1910 the fish of year-class V formed 9·9 per cent. of the sample, being the second largest of the year-classes present. These fish were born in 1905. In 1911 these 1905 born fish belong to the VI class, and again they are second in importance with 17·3 per cent. The class occupies the same position in 1912 and in 1913, when the fish are seven and eight years old respectively. Similarly the fish born in 1899 form the VIII group in 1907, the IX group in 1908, and the X group in 1909, the group in each case being present in considerably greater numbers than fish of the adjacent groups.

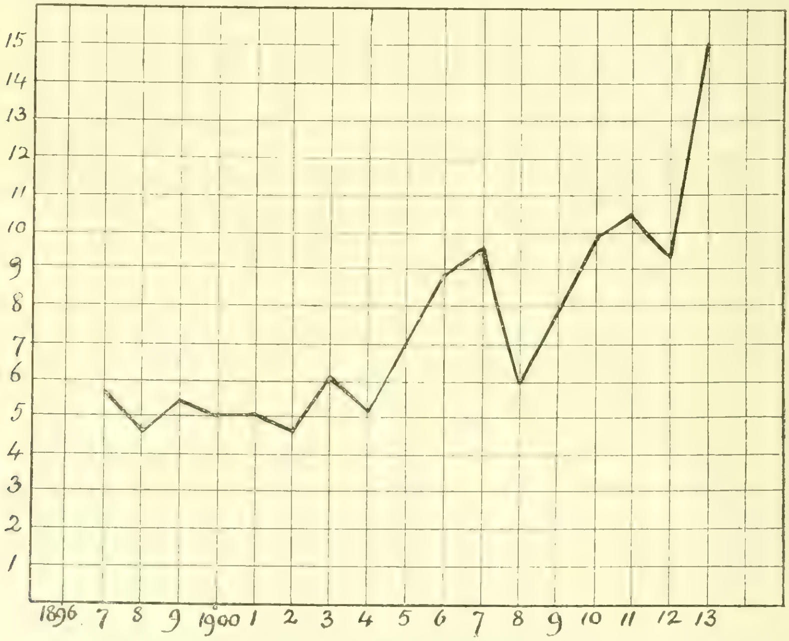


FIG. 9.—Yield of the Norwegian spring herring fisheries for the years 1896–1913. 15 = 1,500,000 hectolitres. 1 hectolitre = 22 gallons. (After Hjort.)

The herring fishery is one which is subject to very great fluctuations from year to year, and to those who have watched the fishery for many years it is a well-recognized fact that bad and good years often run in series. After a number of poor or average years the fishing begins to improve and remains successful for three or four years in succession. In the case of the Norwegian Spring Herring fishery the years from 1909 to 1913, when the fish of the 1904 class predominated, were exceptionally good years, with a very high yield, the year 1913 especially being the best fishery during the whole period from 1896 to 1913 (Fig. 9).

We are furnished, therefore, with what appears to be a distinct step in advance in our attempts to find a rational explanation of the fluctuations in the fisheries. A season occurs in which the conditions are exceptionally favourable for the production of young fish, either owing to an exceptional supply of nourishment upon which the larvæ and fry can feed, or to the absence of enemies, or to some other cause which at present has not been traced. As these fish grow up they year by year come to form a more important factor in the yield of the fishery and the abundance of fish caught increases. In the case we have considered the Herrings born in 1904 dominated and rendered fruitful the fishing of the six years from 1909 to 1914. How much longer their influence will be felt remains to be seen.

What appears to be an exactly parallel case occurred in the North Sea Haddock fishery, and curiously enough it was again fish of the year 1904 that were exceptionally abundant. The young fish of 1904 began to show in the catches in 1905, and in 1906 they were present in extraordinary numbers (Helland-Hansen, **10**, p. 33). Although the case has not been worked out in the same detail as for the Herring, the statistics show an exceptional quantity of medium-sized Haddock in 1907, and of large Haddock from 1907 to 1910. This is just what we should expect from the gradual growth of the fish born in 1904, which were so exceptionally abundant in 1906.

For the Plaice also it has been shown that the abundance of the young brood on the nursery grounds varies greatly from year to year (Johansen, **14**, Pts. III and VI), and there is little doubt that the same sequence of events occurs in the case of this fish, though it has not up to the present been followed in detail.

These investigations, then, seem to give us one of the keys necessary for a proper understanding of much in relation to the fluctuations of the fisheries which was previously difficult to understand. Moreover, they offer a prospect of enabling us to predict the probable course of the fishery some years ahead, for when the exceptional abundance of the young fish of any year has been discovered, we shall be able to say, from a knowledge of the growth-rate of the fish, in how many years these fish will reach marketable size and if all goes well with them give rise to an abundant fishery. Information of this kind, intelligently applied, ought to be of some use to the practical fisherman. To those whose duty it is to study the fisheries from the point of view of legislative or administrative control, it is of course of the very greatest importance.

As was explained at the beginning of this address, I have attempted to lay before you some account of one single branch of fishery research, and as I have proceeded you will no doubt have felt that a subject which at first sight seemed fairly straightforward and simple developed quite unexpected complexity, and yielded in the end quite unexpected results. This is indeed only the common experience of those who break new ground or explore new territories in any branch of knowledge whatever, but in the case of marine research the difficulties are perhaps exceptionally great and the calls on the patience and perseverance of the investigator are almost unlimited. But those who have been most intimately associated with this research and have followed it in greatest detail are the most convinced of its promise of fruitful result. We must look to the growing intelligence of the larger public, grown wiser, may we hope, in the stern school of war, for that appreciation which will enable it to be continued with the means and resources which its difficulties demand.

LIST OF LITERATURE.

1. Apstein. Die Bestimmung des Alters pelagisch lebender Fischeier. *Mitt. Deutsch. Seefisch. Ver.* XXV. 1909, p. 364.

2. Borley, J. O. Report on the Experimental Transplantation of Plaice to the Dogger Bank. *Mar. Biol. Assocn. Internat. Invest. Report.* IV. [Cd. 6125.] 1912.

3. Dahl, K. The Scales of the Herring as a means of determining Age, Growth and Migration. *Rep. Norw. Fish. and Marine Invest.* Vol. II. No. 6. 1907.

4. Damas, D. Contribution à la Biologie des Gadides. *Conseil Internat. pour l'Explor. de la Mer. Rapp. et Proc. Verb.* X. 1909.

5. Dannevig, H. The Influence of Temperature on the Development of the Eggs of Fishes. *13th Ann. Rep. Fish. Board Scotland.* Pt. III, p. 147. 1895.

6. Fabre-Domergue et Biétrix. Développement de la Sole. *Paris.* 1905.

7. Garstang, W. Experiments in the Transplantation of small Plaice to the Dogger Bank. *Mar. Biol. Assocn. Internat. Invest. Report.* I. [Cd. 2670.] 1905.

8. Garstang, W. The Distribution of the Plaice in the North Sea, Skagerak and Kattegat, according to Size, Age and Frequency. *Cons. Internat. p. l'Explor. de la Mer. Rapp. et Proc. Verb.* XI. 1909.

9. Heincke, Fr. Bericht über die Untersuchungen der Biologischen Anstalt auf Helgoland zur Naturgeschichte der Nutzfische. *Beteil. Deutschl. Internat. Meeresforsch.* IV–V. 1908.

10. Helland-Hansen, B. Statistical Research into the Biology of the Haddock and Cod in the North Sea. *Conseil Internat. pour l'Explor. de la Mer. Rapp. et Proc. Verb.* X. 1909.

11. Hjort, J., and Petersen, C. G. J. Short Review of the results of the International Fisheries Investigations. *Conseil Internat. pour l'Exploration de la Mer. Rapp. et Proc. Verb.* III. Appendix G. 1905.

12. Hjort, J. Fluctuations in the Great Fisheries of Northern Europe viewed in the light of Biological Research. *Cons. Internat. pour l'Explor. de la Mer. Rapp. et Proc. Verb.* Vol. XX. 1914. (Contains on pp. 10–13 a list of the principal memoirs on the Age of the Herring.)

13. Hoffbauer, C. Die Altersbestimmung des Karpfens an seiner Schuppe. *Allgemeine Fisch. Zeit.* 1898. No. 19.

14. Johansen, A. C. Contributions to the Biology of the Plaice. *Medd. Komm. Havunters. Fisk.* Pt. I in Bd. I, No. 2, 1905 ; Pt. II in Bd. II, No. 5, 1907 ; Pt. III in Bd. III, No. 4, 1908 ; Pt. IV in Bd. III, No. 5, 1908 ; Pt. V in Bd. IV, No. 1, 1912 ; Pt. VI, Bd. IV, No. 4, 1913 ; Pt. VII, Bd. IV, No. 9, 1915.

15. Johansen, A. C. Bericht über die dänischen Untersuchungen über die Schollenfischerei. *Med. Komm. Havunters. Fisk.* Bd. III, 8. 1910.

16. Johansen and Krogh. The Influence of Temperature and certain other Factors upon the Rate of Development of the Eggs of Fishes. *Cons. Internat. p. l'Expl. de la Mer. Publ. de Circons.* No. 68. 1914.

17. Lee, R. M., and Atkinson, G. T. Report on Plaice Transplantation Experiments to various Fishing Grounds in the North Sea. *Mar. Biol. Assocn. Internat. Invest. Report.* IV. [Cd. 6125.] 1912.

18. Masterman, A. T. Report on Investigations upon the Salmon with special reference to Age-determination by Study of Scales. *Bd. of Agric. and Fisheries. Fishery Investigations.* Ser. I. Vol. I. 1913.

19. Petersen, C. G. J. On the Biology of our Flatfishes. *Report Danish Biol. Sta.* IV. 1893 [1894].

20. Redeke, H. C. Bericht über die hollandische Schollenfischerei und über die Naturgeschichte der Scholle in der südlichen Nordsee. *Verhand. Rijks. Instit. v. onderzoek der Zee.* II, 5. 1909.

21. Reibisch, J. Eizahl bei *Pl. platessa* und die Altersbestimmung dieser Form aus den Otolithen. *Wissensch. Meeresunters.* N.F. Bd. IV. Kiel. 1899.

22. Thompson, Stuart. The Periodic Growth of Scales in Gadidæ as an index of Age. *Journ. Mar. Biol. Assoc.* VI, 1902, and VII, 1904.

23. Wallace, W. *Mar. Biol. Assoc. International Investigations.*
 Report I (1902–03) [Publ. 1905];
 Report II (1904–05) Pt. I [Publ. 1907];
 Report II (1904–05) Pt. II [Publ. 1909];
 Report III (1906–08) [Publ. 1911].

24. Wallace, W. Report on the Age, Growth and Sexual Maturity of the Plaice in certain parts of the North Sea. *Bd. of Agric. and Fisheries. Fishery Investigations.* Ser. II. Vol. II. No. 2. 1915.

25. Winge, O. On the Value of the Rings in the Scales of the Cod as a means of Age Determination. Illustrated by Marking Experiments. *Medd. Komm. Havunders. Fisk.* IV. No. 8. 1915.

For further references to the literature of the subject see:

Dahl, K. The Assessment of Age and Growth in Fish. *Internat. Rev. Hydrobiol. and Hydrogr.* II, 1909, p. 758.

British and Metric Measures.

To convert millimetres to inches multiply by ·039.
,, ,, centimetres ,, ,, ,, ·39.

The following equivalents will be useful in reading this paper:—

1 mm. = $\frac{1}{25}$ inch.
3 ,, = $\frac{1}{10}$,,
6 ,, = $\frac{1}{4}$,,
13 ,, = $\frac{1}{2}$,,

1 cm. = $\frac{2}{5}$ inch.	25·4 cm. = 10 inches.
2·5 ,, = 1 ,,	30·5 ,, = 12 ,,
5 ,, = 2 inches.	35·6 ,, = 14 ,,
10 ,, = 4 ,,	40·6 ,, = 16 ,,
15·2 ,, = 6 ,,	50·8 ,, = 20 ,,
20·3 ,, = 8 ,,	100 ,, = 39 ,,

Marine Biological Association of the United Kingdom.

Report of the Council, 1916.

The Council and Officers.

Four ordinary meetings of the Council have been held during the year, at which the average attendance was nine. A Committee of the Council visited and inspected the Plymouth Laboratory during the Easter Vacation.

The Council has to record with regret the death of Sir Richard Martin, Bart., who for a number of years was a Governor, representing the Worshipful Company of Fishmongers.

The meetings of the Council have been held in the Rooms of the Royal Society, and the thanks of the Association are due to the Society for its hospitality.

The Plymouth Laboratory.

It has been found necessary to replace the gas engine used for circulating the sea-water through the tanks of the Aquarium and of the upstairs Laboratory. The old engine had worked continuously, for practically twenty-four hours a day, for fifteen years, so that good service had been rendered. A new engine was obtained from Messrs. Crossley Bros., fitted with the latest improvements. The other machinery has been maintained in working order, and the buildings are in a satisfactory state of repair, though expenditure under these heads has been kept as low as possible on account of the war.

The Boats.

The steamer *Oithona* is still laid up at Hooe Lake and it is not proposed to put her in commission at present. The eighteen-foot sailing-boat has been used for such collecting work as has been possible in the immediate neighbourhood of Plymouth Sound. As in former years many specimens have been obtained from the local fishermen.

The Staff.

The salaried staff has consisted of the Director (Dr. E. J. Allen, F.R.S.), Mr. D. J. Matthews, Miss M. V. Lebour, and Mrs. Matthews.

The Council is glad to be able to report that Mr. R. S. Clark, who left the Laboratory in 1914 as biologist to Sir Ernest Shackleton's Antarctic Expedition, has returned safely and in good health to this country, after forming one of the party who remained on Elephant Island.

Dr. Allen was appointed President of the Devonshire Association for the Advancement of Science, Literature and Art for the meeting held in Plymouth in July, 1916, and delivered an address on the age of fishes and the rate at which they grow.

Occupation of Tables.

The following Naturalists have occupied tables at the Plymouth Laboratory during the year :—

Miss Crump, London (Oscarella).
W. De Morgan, Plymouth (Protozoa).
H. S. Holden, M.SC., Nottingham (Marine Algæ).
Mrs. E. W. Sexton, Plymouth (Gammarus).
Dr. C. Shearer, F.R.S., Cambridge (Dinophilus).

The usual Easter Vacation Course in Marine Biology for University students was not held this year.

General Work at the Plymouth Laboratory.

In the number of the Journal issued during the year Miss M. V. Lebour has published a description, with detailed illustrations, of the different stages in the life history of the Copepod, *Calanus finmarchicus*. The material upon which this description is based was obtained by Mr. L. R. Crawshay, who reared the animals from the egg, under experimental conditions in the Laboratory.

In the same number of the Journal Dr. Orton gave an account of the researches which had been carried out in the Laboratory on races of herrings, and Mr. D. J. Matthews reported on the amount of Phosphoric Acid found in sea-water off Plymouth Sound. Two further papers by Miss Lebour dealt with the life history of the sea-spider *Anaphia petiolata*, the larvæ of which are carried about by medusæ, and also recorded the fact that medusæ act as hosts for larval Trematodes, the adult form of the worm found in the jelly-fish being known to occur in the mackerel.

A paper by Mrs. Sexton and Miss Wing gave an account of a lengthy series of experiments on the inheritance of eye-colour in the Amphipod *Gammarus chevreuxi*, which was found to be in accordance with Mendel's law.

During the year the Director has completed a report upon the post-larval stages of fishes collected off Plymouth in 1914. A number of interesting stages not previously known have been found.

The experiments on the growth of the scales of fishes kept in the Laboratory tanks under different conditions, especially as regards temperature, were continued until the autumn of 1916. The material is being examined and reported upon by Mr. D. W. Cutler.

Mrs. Matthews' experiments on the rate of growth of fishes kept in the Laboratory and fed with food of different kinds have been continued and extended, and a considerable number of data have been brought together, which will, it is hoped, yield results of importance.

Mr. Matthews, working half-time, has completed his determinations of Phosphoric Acid in the sea off Plymouth. The results extend over a period of sixteen months, showing a large seasonal variation, and will be published in the next number of the Journal. He has also continued his experiments on the methods of determining nitrates in sea-water. The other half of his time has been given to investigations into cerebro-spinal meningitis for the Medical Research Committee, the chemical work being carried out in the Laboratory of the Association.

Miss M. V. Lebour has carried out for a complete year the periodical examination of the micro-plankton found at the mouth of Plymouth Sound. The material has been obtained by centrifuging samples of sea-water taken at different depths, and the results have been worked out quantitatively. At the same time samples of plankton taken with ordinary silk tow-nets have been examined. Miss Lebour's work has added greatly to our knowledge of the smallest plankton organisms and many new records have been obtained, especially amongst the Peridinidæ. A full account of this work has been prepared for publication in the Journal.

Miss Lebour has since commenced to study the actual food found in larval and post-larval fishes, which feed upon plankton organisms. This is largely a new field of investigation, which is already giving promise of results of considerable interest.

Mr. W. De Morgan has been again engaged in studying the marine protozoa, and Mrs. E. W. Sexton has extended and developed the studies on the Mendelian inheritance of eye-colour in *Gammarus* referred to above.

Published Memoirs.

The following papers, either wholly or in part the outcome of work done at the Laboratory, have been published elsewhere than in the Journal of the Association :—

DUNCAN, F. MARTIN. *Studies in Marine Biology.* Journ. Roy. Micr. Soc., 1916, pp. 257–261.

KRAMP, P. L. *Spontaneous Fission in Hydroids.* Vidensk. Meddel. fra Danske naturh. Foren., Bd. 67, 1915, pp. 211–219.

MATTHEWS, A. *The Development of Alcyonium digitatum, with some notes on the Early Colony Formation.* Quart. Jour. Micr. Sci., vol. 62, 1916, pp. 43–94.

The Library.

The thanks of the Association are due to numerous Government Departments, Universities and other institutions at home and abroad for copies of books and current numbers of periodicals presented to the Library. The list is similar to that published in the Reports of Council of former years. A number of authors have been good enough to send reprints of their papers for the Library, and to these also thanks are due.

Donations and Receipts.

The receipts for the year include a grant from H.M. Treasury of £500, being on account of the war one-half of the sum granted in recent years, a grant from the Board of Agriculture and Fisheries' Development Fund (£400), and one from the Fishmongers' Company (£600). In addition to these grants there have been received Annual Subscriptions (£104), Rent of Tables in the Laboratory, including £25 from the University of London and £20 from the Trustees of the Ray Lankester Fund (£50); Sale of Specimens (£313) and Admission to Tank Room (£89).

Vice-Presidents, Officers, and Council.

The following is the list of gentlemen proposed by the Council for election for the year 1917–18:—

President.

Sir E. Ray Lankester, K.C.B., LL.D., F.R.S.

Vice-Presidents.

The Duke of Bedford, K.G.
The Earl of Ducie, F.R.S.
The Earl of Stradbroke, C.V.O., C.B.
Lord Montagu of Beaulieu.
Lord Walsingham, F.R.S.
The Right Hon. A. J. Balfour, M.P., F.R.S.
The Right Hon. Austen Chamberlain, M.P.
W. Astor, Esq., M.P.
G. A. Boulenger, Esq., F.R.S.
A. R. Steel-Maitland, Esq., M.P.
Rev. Canon Norman, D.C.L., F.R.S.
Edwin Waterhouse, Esq.

Members of Council.

Prof. W. M. Bayliss, F.R.S.
E. T. Browne, Esq.
L. W. Byrne, Esq.
W. C. De Morgan, Esq.
Prof. H. J. Fleure, D.Sc.
E. S. Goodrich, Esq., D.Sc., F.R.S.
E. W. L. Holt, Esq.
Prof. E. W. MacBride, F.R.S.
H. G. Maurice, Esq., C.B.
P. Chalmers Mitchell, Esq., D.Sc., F.R.S.
C. C. Morley, Esq.
F. A. Potts, Esq.
C. Tate Regan, Esq., F.R.S.
Prof. D'Arcy W. Thompson, C.B., F.R.S.

Chairman of Council.

A. E. Shipley, Esq., D.Sc., F.R.S.

Hon. Treasurer.

George Evans, Esq., 1 Wood Street, London, E.C. 2.

Hon. Secretary.

E. J. Allen, Esq., D.Sc., F.R.S., The Laboratory, Citadel Hill, Plymouth.

The following Governors are also members of the Council:—

G. P. Bidder, Esq., Sc.D.

Sir Matthew I. Joyce (Prime Warden of the Fishmongers' Company).

The Earl of Portsmouth (Fishmongers' Company).

The Hon. Nathaniel Charles Rothschild (Fishmongers' Company).

T. T. Greg, Esq. (Fishmongers' Co.).

George Evans, Esq. (Fishmongers' Company).

Prof. G. C. Bourne, D.Sc., F.R.S. (Oxford University).

A. E. Shipley, Esq., D.Sc., F.R.S. (Cambridge University).

Prof. W. A. Herdman, D.Sc., F.R.S. (British Association).

THE MARINE BIOLOGICAL ASSOCIATION

Dr. *Statement of Receipts and Payments for*

	£	s.	d.	£	s.	d.
To Balance from Last Year :—						
Cash at Bankers	852	0	2			
Cash in hand	17	12	10	869	13	0
,, Current Receipts :—						
H.M. Treasury for the year ending 31st March, 1917	500	0	0			
The Worshipful Company of Fishmongers	600	0	0			
Annual Subscriptions	104	7	11			
Rent of Tables (including Ray Lankester's Trustees, £20; University of London, £25)	50	0	0			
Interest on Investments	12	18	8			
,, Deposit	6	16	9	1,274	3	4
,, Extraordinary Receipts :—						
Donation, G. H. Fox	0	10	6			
Board of Agriculture and Fisheries, Grant from Development Fund for year ending 31st March, 1917	400	0	0			
Naval Bank—Dividend	3	19	7	404	10	1
,, Laboratory Boats and Sundry Receipts :—						
Sales of Apparatus	14	10	2			
,, ,, Specimens	313	9	6			
,, ,, Nets, Gear, etc.	0	7	6			
Other Items	1	1	0	329	8	2
				£2,877	14	7

The Association's Bankers hold on its behalf £410 14s. 8d. New Zealand 4% Stock, 1943–63.

OF THE UNITED KINGDOM.

the Year ending 31*st December*, 1916. **Cr.**

	£	s.	d.	£	s.	d.
By Salaries and Wages—						
Director	300	0	0			
Hydrographer	150	0	0			
Senior Naturalist	51	3	0			
Additional ,,	131	15	6			
Temporary ,,	150	13	0			
Assistant ,,	12	15	0			
,, ,, (temporary)	1	5	0			
Salaries and Wages	470	11	3	1,268	2	9
,, Travelling Expenses				17	15	9
,, Library				47	19	6
,, Journal	90	0	11			
Less Sales	18	15	7	71	5	4
,, Buildings and Public Tank Room—						
Gas, Water, and Coal	140	13	11			
Stocking Tanks and Feeding	34	16	0			
Maintenance and Renewals	97	18	7			
Rent, Rates, Taxes, and Insurance	54	17	6			
	328	6	0			
Less Admission to Tank Room	89	4	8	239	1	4
,, Laboratory, Boats, and Sundry Expenses—						
Glass, Apparatus, and Chemicals	81	6	11			
Purchase of Specimens	27	2	1			
Maintenance and Renewals of Boats, Nets, etc.	95	4	1			
Boat Hire and Collecting Expenses	4	5	0			
Coal for Steamer	1	1	0			
Stationery, Office Expenses, Carriage, Printing, etc.	85	14	2	294	13	3
,, Balance:—						
Cash at Bankers	927	16	6			
Cash in hand	11	0	2	938	16	8
				£2,877	14	7

Examined and found correct,

(Signed) N. E. Waterhouse.
Portsmouth.
Thomas T. Greg.
C. Tate Regan.

3 *Frederick's Place,*
Old Jewry, London, E.C.
25*th January*, 1917.

The Food of Post-Larval Fish.

By

Marie V. Lebour, D.Sc.
Naturalist at the Plymouth Laboratory.

With Figures 1–7 in the Text.

CONTENTS

PAGE
Introduction 434
Labrus bergylta 439
Caranx trachurus 439
Scomber scomber 439
Trachinus vipera 440
Lophius piscatorius 440
Cottus bubalis 440
Trigla gurnardus 440
Agonus cataphractus 440
Blennius galerita 441
Blennius gattorugine 441
Gobius minutus 441
Gobius sp. (a) 441
Gobius sp. (b) 441
Crystallogobius Nilssoni 442
Callionymus lyra 442
Cyclogaster Montagui 442
Cyclopterus lumpus 442
Lepadogaster Candollei 442
Lepadogaster gouani 443
Rhamphistoma belone 443
Pleuronectidæ 443
Solea vulgaris 445
Solea lascaris 446
Solea variegata 446
Pleuronectes limanda 450
Pleuronectes flesus 450
Pleuronectes microcephalus 451
Arnoglossus sp. 451
Rhombus maximus 452
Rhombus lævis 452
Zeugopterus punctatus 452
Zeugopterus unimaculatus 452
Scophthalmus norvegicus 453
Gadidæ 454

	PAGE
Gadus morrhua	454
Gadus merlangus	454
Gadus luscus	455
Gadus pollachius	455
Gadus minutus	455
Onos mustela	456
Ammodytes tobianus	456
Ammodytes lanceolatus	456
Gasterosteus spinachia	456
Syngnathus acus	456
Syngnathus rostellatus	457
Nerophis lumbriciformis	457
Clupea harengus	457
Clupea sprattus	459
Literature	460
Table of Post-larval fish from tow-nets	461

ALTHOUGH much investigation has been made on the food of adult fish the information as to the food of the very young is scattered and fragmentary. It is the purpose of this paper to report on the food of a number of post-larval fish which have been examined fresh from the tow-nettings through the year 1917 from Plymouth Sound within the Breakwater and outside as far as the region of the Panther and Knap Buoys (about 2½ miles from the shore) and occasionally from Cawsand Bay. The food of a number of preserved post-larval fish has also been investigated which were taken in the Young Fish Trawl in 1914 and reported on by Dr. Allen (1917). These latter were mostly examined as mounted and cleared preparations, the food usually being plainly seen. Others from this lot were examined by dissecting out the alimentary canal—a method not so satisfactory for preserved material although answering very well for the fresh fish which were all examined by this latter method.

A systematic examination of post-larval fish from tow-nettings was made by A. Scott (1906), who used the above methods, but the number examined was not large. Herdman (1893–1898) had also previously noted the contents of the alimentary canal in several young fish, chiefly those beyond the post-larval stages. Petersen (1894, 1917) also notes the food of young fish, especially *Pleuronectidæ*. Other records have chiefly to do with the food of artificially reared fish, when the food picked out by the post-larval fish from plankton given to them is noted.

In all these records it is found that the Copepoda form the chief food of nearly all larval and post-larval fish with other Entomostraca and Mollusk larvæ. It now seems to be a well established fact that the majority of young fish eat the small animals from the plankton more than the diatoms and other unicellular organisms, except in cases of some of the very young fish which have been found to eat diatoms before taking to animal food (Kyle (1898) found Dab from 10 to 16 mm. with stomachs full of diatoms), and in the few exceptional cases of fish which are true vegetarians. As examples of these latter cases Herdman (1912) shows that post-larval plaice first feed on diatoms before taking animal food; Dannevig (1897 and 1898) also found that the young plaice first took diatoms and in some cases Infusoria. The Grey Mullet which is herbivorous, with its mouth-parts adapted for browsing, eats in its post-larval stage according to Cunningham (1890) chiefly diatoms, although A. Scott (1898) has found that the older young eat Copepods as well as diatoms. Professor S. A. Forbes (1882–1884) shows that the young Whitefish (*Coregonus clupeiformis*) in a tank with only vegetable food nearly all died, whilst they fed eagerly on Entomostraca. Even before the yolk is absorbed a pair of small teeth are developed, well adapted for seizing animal food such as these small Crustacea (chiefly Copepods). Young herring take Mollusk larvæ before the yolk is absorbed, as do also the pipe-fish, *Nerophis lumbriciformis*, which hatched in a jar in the laboratory. Mollusk larvæ seem often to be taken very early, even before Copepods.

That a certain amount of selection of food takes place is evident from previous records and from our own observations. Dannevig (1897) states that only one species at one time was eaten by the baby plaice although different individuals might eat different species. It seemed as though one individual got used to a certain food and stuck to it for a time. Petersen (1894) shows that the Dab, living with the Plaice, selects Copepods of other species from those chosen by the latter fish, and Herdman shows that the natural food of fish is often that which is not most frequently present, so that the fish must hunt for it.

The following records show that certain fish undoubtedly prefer certain food; frequently two or three fish will like the same kind. For instance, *Solea variegata* and the few *Solea vulgaris* examined like the same food as the Dab, *e.g.* chiefly *Podon*, *Temora* and *Euterpina*, so that it may well be that the very abundant Dab takes away, in its very young stages, the food from its more valuable relatives. It is to be noted, however, that whereas Solea eats Crustacea as big as *Temora* almost at once, the Dab, *Pleuronectes limanda*, has a period up to about 5 mm. when no Crustacea are found in its alimentary canal, so that it most probably first eats softer food. It is not in the least the case that all Pleuronectids eat the same food, for one of the Top-knots, *Scophthalmus norvegicus*, specially eats *Pseudocalanus*, which is only very rarely found in the Soles and Dab, and *Arnoglossus* although not eating Copepods for some time also likes *Pseudocalanus*. *Podon*, probably *P. intermedius*, is a favourite with many young fish, and is often taken by the very young ones before Copepods; probably it is more easily digested. It heads the list of the food of post-larval fish in these records.

As regards the Copepods, we naturally find that the fish with the smallest mouths eat the smallest forms, both large and small being eaten by those with large mouths. Thus *Arnoglossus* up to about 20 mm. having a small mouth does not take larger forms than *Pseudocalanus*, whereas *Solea variegata* at 4 mm. can eat full-grown *Temora*, and *Scophthalmus norvegicus* at 4·5 mm. can eat full-grown *Metridia lucens*. It is a striking fact that *Calanus finmarchicus*, which is abundant, is eaten very little by these post-larval fish. It is apparently too large for any but the fair-sized young ones. The nauplii are seen oftener as food for the small ones, and probably are frequently among the unidentifiable Copepod remains. Fish caught in the act of swallowing Copepods always show the tail sticking out of the mouth, so that they are swallowed head first.

The commonest food in order of frequency is the following: *Podon* (probably *intermedius*), *Pseudocalanus elongatus*, *Temora longicornis* and *Euterpina acutifrons* in the proportion of 6 : 4 : 3 : 2, *Metridia lucens* and *Balanus nauplii* coming next, and afterwards other Copepods such as *Oncæa* sp., *Acartia* sp. *Corycæus anglicus*, *Centropages typicus*, *Calanus finmarchicus* in order, with nauplii especially of *Temora* and in very few cases *Microsetella norvegica*, *Harpacticus uniremis*, *Longipedia Scotti*, *Isias clavipes*, *Idya furcata*, *Oithona similis* and *Anomalocera pattersoni*. Cypris stages of *Balanus* occurred at certain times and *Evadne* sp. *Podon* and *Evadne* are not found in the winter but most of the fish that had eaten *Podon* were in summer hauls, and the *Balanus* nauplii which swarm in spring, beginning in February, were chiefly taken by young herring. The Copepods most frequently taken as food are amongst the commonest in the ordinary tow-nettings, although the Harpacticid *Euterpina acutifrons* occurs much more frequently in fish than in the tow-nettings, and the *Oncæa* (probably *media*) has not been taken with the tow-nets here. These two and *Metridia lucens* are evidently commoner outside, and the hauls in which the fish were taken which had chiefly eaten these were from the region of the Eddystone and Rame Head, the other common forms, *Podon*, *Temora* and *Pseudocalanus* also evidently abounding there. Besides Copepods and Cladocera small ova were frequently found in the fishes, especially the Pleuronectids and Herring; these were spherical and usually measured about 0·2 mm. in diameter. The very young fish frequently contained only these.

Very few unicellular organisms besides these ova were found in the young fish. Diatoms when present were sometimes in the Copepods eaten or in their fæces, but not very often free in the alimentary canal. In one instance a perfect specimen of a *Coccosphæra* was found in a Pouting, *Gadus luscus*. On another occasion a young *Ammodytes* contained several *Rhizosolenia Shrubsolei*.

To show that a certain amount of selection does take place a list was made of the food inside the fish from 2 hauls, and the food of each fish noted. For this purpose Hauls XIII and XIIIa were selected, both with the Young Fish Trawl, 1914. Haul XIII May 19th, 11.35 p.m. Mid-water, Eddystone, N. 6½, 39 fms. Haul XIIIa May 22nd, Eddystone, S.W. 3 miles, 28 fms.

Haul XIII.

Contained the following fish :—

406	*Clupea* sp.
1	*Ammodytes* sp.
8	*Gadus merlangus.*
7	*G. luscus.*
158	*G. minutus.*
5	*Onos mustela.*
1	*Labrus bergylta.*
70	*Pleuronectes limanda.*
55	*P. microcephalus.*
1	*Arnoglossus* sp.
84	*Scophthalmus norvegicus.*
1	*Zeugopterus unimaculatus.*
4	*Z. punctatus.*
48	*Solea variegata.*
5	*Gobius* sp.
150	*Crystallogobius Nillsoni.*
13	*Trigla* sp.
20	*Callionymus lyra.*

These contained the following food :—

Diatomaceæ.

Paralia sulcata.
Pleurosigma sp.
Navicula sp.
Guinardia flaccida.
Lauderia borealis.

Peridiniales.

Dinophysis sp.
Diplopsalis lenticula.
Prorocentrum micans.
Peridinium ovatum.
P. pallidum.
P. cerasus.
P. sp.

Infusoria.

Tintinnopsis ventricosa.

Cirripedia.

Balanus nauplii and cypris stages.

Cladocera.

Podon (cf. *intermedius*).

Copepoda.

Calanus finmarchicus.
Pseudocalanus elongatus.
Metridia lucens.
Paracalanus parvus.
Temora longicornis.
Acartia (cf. *Clausi*).
Oncœa (cf. *media*).
Coryceus anglicus.
Euterpina acutifrons.
Also ova.

The Diatoms and Peridiniales were nearly all inside the Copepods. The Copepods chiefly taken were *Pseudocalanus*, *Temora*, *Euterpina* and *Metridia*. *Solea variegata* and *Pleuronectes limanda* ate chiefly *Podon* and *Temora*, *Solea* also eating *Euterpina*, *Oncœa*, *Corycœus* and *Balanus* larvæ, neither containing *Pseudocalanus*. On the other hand *Pseudocalanus* was the chief food of *Scophthalmus norvegicus*, which hardly ever took *Temora*, but in addition to *Pseudocalanus* contained

Metridia and occasionally *Podon*, *Acartia*, *Paracalanus*, *Oncæa* and *Euterpina.* *Pseudocalanus* was also almost the only food of *Gadus minutus* and *G. merlangus.* The *Clupea* were all empty and no food was found in *Pleuronectes microcephalus.* Those of the *Crystallogobius* examined (not all as they were almost adult) contained *Calanus finmarchicus*, showing that it was present although not taken by the other fish. *Callionymus lyra* eats almost anything. Besides the above food, many of the fish contained ova.

Haul XIIIa.

Contained the following fish :—

45 *Pleuronectes limanda.*
11 *Solea variegata.*
1 *S. vulgaris.*
10 *Zeugopterus punctatus.*
2 *Scophthalmus norvegicus.*
59 *Gadus* sp.
8 *Trigla* sp.
1 *Labrus bergylta.*
1 *Ammodytes* sp.
34 *Callionymus lyra.*

The fish contained the following food :—

PERIDINIALES.

Peridinium ovatum.
P. sp.

INFUSORIA.

Tintinnopsis ventricosa.

CLADOCERA.

Podon (cf. *intermedius*).

COPEPODA.

Calanus finmarchicus.
Pseudocalanus elongatus.
Paracalanus parvus.
Temora longicornis.
Centropages typicus.
Acartia (cf. *Clausi*).
Oncæa (cf. *media*).
Idya furcata.
Euterpina acutifrons.

AMPHIPODA.

Apherusa (cf. *Clevei*).

Thus the two hauls contain very similar food. Again we find that *Solea variegata* ate chiefly *Temora*, also *Euterpina* and occasionally *Oncæa* and *Acartia* but no *Pseudocalanus.* *Solea vulgaris* ate *Temora* and *Euterpina* and *Pleuronectes limanda* chiefly *Temora* and *Podon* but not *Pseudocalanus.* *Zeugopterus punctatus* ate chiefly *Temora* but also *Calanus*, *Oncæa* and *Euterpina.* Again *Scophthalmus norvegicus* ate chiefly *Pseudocalanus*, although *Paracalanus*, *Euterpina* and *Temora* are present. *Pseudocalanus* is also eaten by the Gadus sp. with several other Copepods including occasional *Calanus*, and by *Trigla* and *Ammodytes.* Again *Callionymus lyra* eats a variety, including *Apherusa.* From these notes it will be seen that certain fish do undoubtedly take certain foods in preference to others, and this is specially well shown in *Solea* and *Pleuronectes limanda*, which like *Podon* and *Temora*, and almost entirely pass over *Pseudocalanus* although present in abundance.

LABRUS BERGYLTA Asc. Ballan Wrasse.

Thirty-nine specimens were examined which came in the tow-nettings from both outside and inside the Breakwater, from June to September, and were examined fresh. They measured from 2·5 mm. to 11 mm., the small specimens being somewhat contracted so that they naturally were longer. The smallest were either empty or contained indistinguishable green food remains, those from 4 to 5 mm. containing almost entirely Copepod nauplii, especially *Temora*, with occasional remnants of diatoms (*Navicula*) and peridinians, with green food remains. At 6 mm. Copepods and Copepod nauplii were taken, one specimen containing the following :—

10 *Cittarocyclis denticulata.*
1 *Temora longicornis.*
3 *Euterpina acutifrons.*
1 *Copepod indet.*
2 *Prorocentrum micans.*
6 *Peridinium* sp.
1 *Lithomelissa setosa.*
1 *Tintinnopsis beroidea.*

The larger specimens contained Copepod remains including *Temora* and *Pseudocalanus*, and also *Podon*. Altogether 20 out of the 39 contained Copepod nauplii or young copepodid stages, so that evidently this, with small planktonic organisms, is their chief food in the post-larval state.

CARANX TRACHURUS L. Horse Mackerel.

Four specimens of young Horse Mackerel were examined, from inside and outside the Breakwater and Cawsand Bay,* in September and October, measuring 30 to 40 mm. They all contained Crustacea, chiefly Copepods including *Calanus*, *Centropages typicus* (15 in one specimen), *Temora* and many Harpacticids, including *Idya furcata*. Crab zoeæ and *Porcellana* larvæ were also present.

SCOMBER SCOMBER L. Mackerel.

Twenty-five Mackerel were examined fresh from the tow-nettings, measuring 3 to 16 mm., from inside and outside the Breakwater from the end of July to the middle of September. The very smallest either contained nothing or green food remains, but one of 3·5 mm. contained 2 *Temora* nauplii and another a larval gastropod. Nine specimens contained nothing, the remainder contained green food remains and Copepod remains which seemed to be almost entirely *Temora* nauplii. The specimen of 16 mm. with remains of Copepods in its alimentary canal had in its mouth (swallowed head first) 4 adult *Temora longicornis* which it had probably taken after capture.

---

* For a Plan of Plymouth Sound showing where the tow-nettings were taken, see Fig. 7, p. 459.

TRACHINUS VIPERA Cuv. Lesser Weaver.

Three specimens examined fresh from the tow-nettings from outside the Breakwater, 2 of 22 mm. in September, 1 of 5 mm. in October. One big one contained indistinguishable Copepod and other Crustacea remains, the other contained one *Pseudocalanus elongatus* and one *Anomalocera Pattersoni.* The small one contained 3 *Pseudocalanus elongatus* and one *Temora* nauplius.

LOPHIUS PISCATORIUS L. Angler.

Six specimens from outside the Breakwater were examined fresh from the tow-nettings in July, measuring 4 to 8·5 mm., 4 contained nothing, the other 2 indistinguishable Copepod remains.

COTTUS BUBALIS Euph. Father Lasher.

Twenty-two specimens, fresh, from the tow-nettings, were examined in March and April from inside and outside the Breakwater, measuring 4·5 to 10 mm. The smallest were however contracted and probably really were longer. The specimen of 10 mm. contained no food, one of 7 mm. contained a *Temora longicornis ;* all the rest, excluding 4 containing nothing, contained green remains, Crustacea remains, diatoms or *Balanus* nauplii. The *Balanus* nauplii were in 7 specimens, and were in the smallest specimens. Evidently *Cottus bubalis* takes a mixed diet. One of 4·5 mm. contained the following :—

2	larval gastropods.
1	*Biddulphia regia.*
1	*Coscinodiscus radiatus.*
15	*Thalassiosira gravida.*

Another specimen also contained *Thalassiosira*, so that here we have one of the post-larval fish which does take diatoms as food.

TRIGLA GURNARDUS L. Grey Gurnard.

Only one specimen of 8 mm., from tow-nettings in the West Channel, contained one *Podon.*

AGONUS CATAPHRACTUS L. Armed Bullhead.

Two specimens, one from inside and one from outside the Breakwater in February and March, examined fresh from the tow-nettings. One contained nothing, the other one *Coscinodiscus excentricus.*

BLENNIUS GALERITA L. Montagu's Blenny.

One specimen from the White Patch, 17 mm. long, fresh from tow-nettings, July, contained 5 *Temora longicornis.*

BLENNIUS GATTORUGINE Bloch.

One specimen from the west end of Breakwater, fresh from tow-nettings, August, contained remains of crab zoeæ and Crangon larvæ.

GOBIUS MINUTUS Pall.

Twenty-four specimens, from both inside and outside the Breakwater, from fresh tow-nettings from July to September, were examined, measuring 2 to 14 mm. The smallest and most of those from 4 to 5 mm. contained no food, but one of 4 mm. contained remains of Copepod nauplii and one of 4·5 mm. contained a *Temora* nauplius. Those of 6 mm. contained Copepod remains including *Calanus* nauplii. From 6 5 mm *Pseudocalanus* was eaten and was in 3 specimens, one of which (14 mm. long) contained 3 *Pseudocalanus* and 4 *Temora.* Another of 14 mm. contained 3 *Acartia* sp. (probably *A. Clausi*).

The other Gobius species have not been identified. I have designated them Gobius sp. (a) and Gobius sp. (b). A third, very small and with orange and yellow pigment, contained no food.

GOBIUS SP. (a).

Nineteen specimens, from both inside and outside the Breakwater, fresh from tow-nettings, measuring 2 to 4 mm., in March and April. Ten contained nothing, one of 3 mm. contained a larval bivalve, one of 3·5 mm. a *Balanus* nauplius. One contained a *Coscinodiscus* and the remainder had green food remains in them.

GOBIUS SP. (b).

This is very like the larva of *Gobius niger* but with less pigment, and possibly may be *G. paganellus.* Nine specimens were examined from both inside and outside the Breakwater, in August fresh from the tow-nettings, measuring 11 to 13 mm. Two contained no food, one the remains of diatoms, including *Skeletonema costatum,* 2 contained green food remains and one a *Balanus* nauplius. The rest contained Copepods, all identified being *Temora,* adult, young and nauplii.

CRYSTALLOGOBIUS NILSSONI v. Düb. & Kor.

One fresh specimen from tow-nettings outside the Breakwater, October, measuring 21 mm. contained nothing. Twenty-eight preserved specimens from Haul XIII Y.F.T. 1914, all contained Crustacea, 13 contained *Podon*, and 2 *Calanus finmarchicus*, many remains probably representing the latter species. The specimens measured from 26 to 37 mm.

CALLIONYMUS LYRA L. Dragonet.

Forty-six fresh specimens from the tow-nettings were examined, from both inside and outside the Breakwater from March to October, from 1·5 to 8 mm. Up to 2 mm. yolk was present but diatoms or green food was sometimes present. *Coscinodiscus excentricus* and *C.* sp. *Paralia sulcata*, *Navicula* sp. and *Pleurosigma* sp. were present, at 3 mm. *Euterpina* was eaten, *Balanus* nauplii occasionally. Many of these small ones were empty.

222 preserved specimens from the Young Fish Trawl 1914 were examined, from 3 to 13 mm. At 3·5 mm. *Pseudocalanus* is eaten. After that a variety of Copepods including *Oncæa*, *Euterpina*, *Corycæus*, *Temora*, *Idya*, *Paracalanus*, *Calanus* and *Centropages*, with occasional *Podon* and *Apherusa*, also ova. The commonest Copepods taken are *Pseudocalanus* and *Euterpina*, *Temora* coming next. *Callionymus lyra* is thus a very miscellaneous feeder, beginning with diatoms when very young and soon feeding almost exclusively on Copepods.

CYCLOGASTER MONTAGUI Donov.

Four specimens from both inside and outside the Breakwater, March and April, 3·5 to 4·5 mm. Two contained nothing ; one, diffuse brownish food remains, and one, remains of Crustacea.

CYCLOPTERUS LUMPUS L. Lump Sucker.

Two specimens from amongst the Zostera outside the Breakwater in July and August, 15 and 18 mm. That of 15 mm. contained 5 Amphipoda indet., and 1 *Harpacticus uniremis*, the other contained remains of *Eupagurus* larvæ and other larval decapods.

LEPADOGASTER CANDOLLEI. Risso.

Nine specimens from both within and outside the Breakwater, July and August, 4 to 8 mm. One of 4 mm. contained two young *Temora*, all the others (except one with nothing in it) contained remains of Copepods, including *Temora* nauplii and Harpacticids.

LEPADOGASTER GOUANI Lacep.

Five specimens from outside the Breakwater, August and October, 4 to 6 mm. The largest contained 1 *Centropages typicus* and 2 *Pseudocalanus elongatus*, 2 contained nothing, and the others Copepod nauplii and Harpacticids.

RHAMPHISTOMA BELONE (L.). Gar-fish.

Sixteen specimens from both within and without the Breakwater, July and August, from amongst Zostera, 10 to 29 mm., 6 contained nothing, 6 contained *Harpacticus uniremis*, the rest greenish food remains and 1 *Pleurosigma* sp.

PLEURONECTIDÆ.

Very few Pleuronectids were obtained fresh from the tow-nettings, but a large number from the Young Fish Trawl, 1914, were examined in a preserved state for food and show some interesting features. Thus we find they fall into two groups according to the form of the alimentary canal, which influences the food taken in the young forms. In the first group we may place those with a large mouth and a thick and short gullet and stomach; to this group belong *Solea variegata*, *S. vulgaris*, *S. lascaris*, *Pleuronectes limanda*, *Rhombus maximus*, *R. lævis*, *Zeugopterus punctatus*, *Z. unimaculatus* and *Scophthalmus norvegicus*. With this character goes the habit of taking such food as small Copepods and Cladocera at an early stage, so that the newly hatched fish very soon, and in some cases almost immediately, takes this food. The Plaice *Pleuronectes platessa* would probably be included in this group although in the very first stages after hatching it is known to eat diatoms and larval mollusks, soon however taking to Copepods and other small Crustacea, especially Entomostraca. The nearest to the Plaice in this respect is the Dab, *P. limanda*, which seems not to begin to eat Copepods until about 5 mm. in length, although it hatches under 3 mm. On the other hand *Solea variegata* hatches at about 2·5 mm. and at 4 mm. it may contain a fairly large *Temora* measuring 1·5 mm. *Scophthalmus norvegicus* hatches at about 2·5 mm. and still has yolk at 3·27 mm., but at 4·5 mm. it can eat a *Metridia* 2 mm. long. In these cases Copepods must be eaten very soon after hatching.

In the second group we may include *Pleuronectes flesus*, *P. microcephalus* and *Arnoglossus laterna* which have a long and narrow gullet and stomach, and these apparently do not eat Copepods or any Crustacea until a greater size is reached—the alimentary canal in the small specimens being either empty or showing indications of a diet of unicellular organisms, ova, diatoms or other microscopic plants. Thus in *Pleuronectes microcephalus* Copepods were only found in very few and these of the smallest kind in the larger fish, ova occurred in many, and diatoms (*Navicula* and *Pleurosigma*) and Peridinians in a few. In Arnoglossus only in those over 8 mm. were there any Copepods (*Pseudocalanus*). *Pleuronectes flesus* from 5·5 to 10 mm. had nothing inside larger than diatoms, but often diffuse masses which were apparently remains of unicellular organisms. Thus we have a great contrast between the two groups and a correlation between a large mouth with a broad, short gullet and stomach and an early diet of Entomostraca, and between a

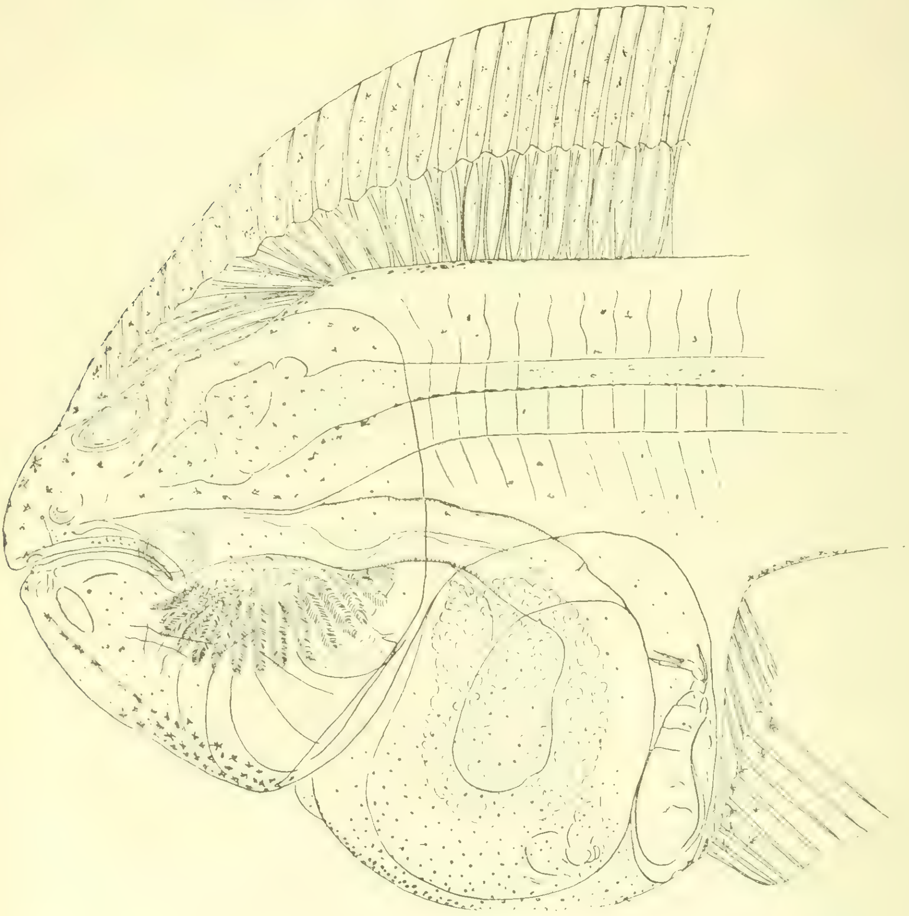


FIG. 1.—Post-larval *Solea variegata* 12 mm. long, from balsam preparation. Eyes seen through from left side.

small mouth with a long and narrow gullet and stomach and an early more or less vegetarian diet, only going on to Entomostraca at a much later stage. (See Figs. 1–6.)

The large-mouthed forms do not all take the same kind of Crustacean food, but certain groups seem to do so. Thus *Solea variegata, S. vulgaris* and *S. lascaris, Pleuronectes limanda, Zeugopterus punctatus* and *Z. unimaculatus* take much the same sort of food, but *Scophthalmus norvegicus* differs in taking *Pseudocalanus* and *Metridia* chiefly, forms hardly taken at all by those mentioned above, *Pseudocalanus* on the other hand being the chief food of the larger post-larval *Arnoglossus.*

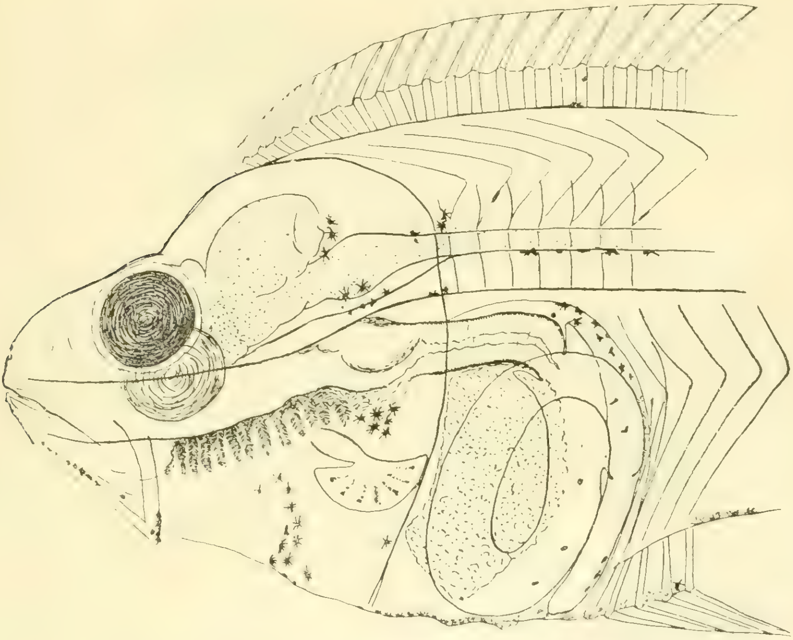


Fig. 2.—Post-larval *Pleuronectes limanda,* 12 mm. long, from a balsam preparation. Right eye seen through from left side.

SOLEA VULGARIS Quensel. Common Sole.

Fourteen specimens examined, preserved, from Young Fish Trawl, 1914, 5·5 to 9·5 mm. The smallest contained Copepod remains, 3 contained nothing, 2 were indistinguishable and 2 contained ova. The rest contained Copepods (*Temora* and *Euterpina* and *Oncæa*), *Balanus* cypris stage and one contained a *Prorocentrum micans.* A. Scott (1906) found in a Sole of 7·5 mm., *Longipedia minor*, *Ectinosoma Sarsi* and *E. Normanni*, all littoral Copepods. Holt and Byrne (1905) state that between 7 and 11 mm. they feed largely on the larvæ of other fishes.

SOLEA LASCARIS Bonap. Lemon Sole.

Two specimens only, preserved, from Young Fish Trawl, 1914, 9·5 and 10·5 mm., one indistinguishable, the other containing *Temora* and *Euterpina*.

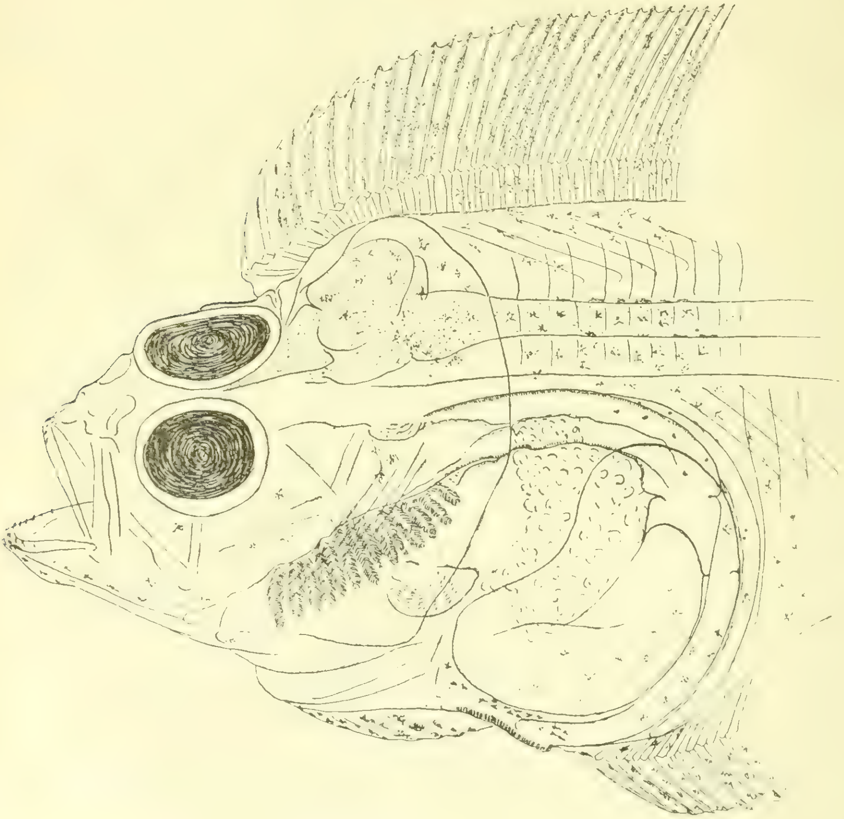


Fig. 3.—Post-larval *Scophthalmus norvegicus*, 12 mm. long.

SOLEA VARIEGATA Donov. Thickback.

221 specimens of the "Thickback" were examined, from the Young Fish Trawl, 1914, preserved. They varied in length from 4 mm. to 11·5 mm., and as it hatches at about 2·5 mm. some of them must be very

young. Twenty-two contained nothing, but the remainder had a good deal of food inside them, the smallest eating the same as the largest. Nearly all the food was Crustacea and small ova of two kinds, one with a tough sheath, the others without, and perhaps being ova of Copepods. The majority of the Crustacea were Copepods, Cladocera (*Podon*) coming next in abundance, and the cypris stage of *Balanus*. Of the Copepods the Harpacticid *Euterpina acutifrons* is the most frequent, occurring in 60 out of the 221 specimens, as many as 5 or 6 often being found in one individual. From May 22nd they are particularly abundant in Hauls XIII to XVII (for particulars of the hauls see Allen (1917) both from the region of the Eddystone and Rame, evening and morning, midwater and surface, and occur in fish from 4 mm. to 10·5 mm. long, very often

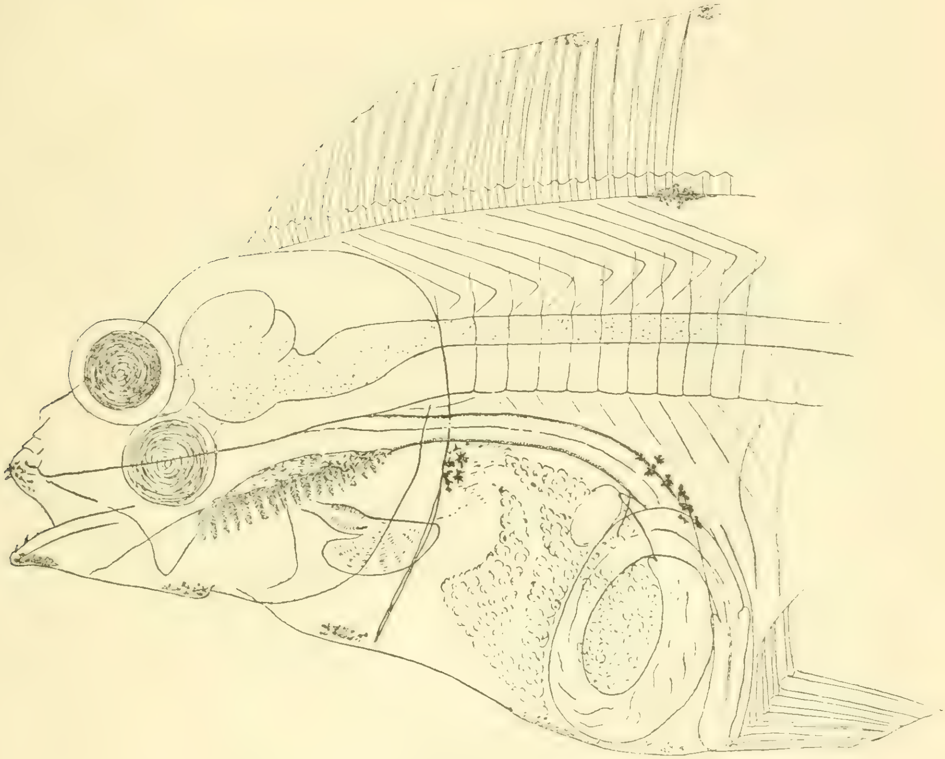


Fig. 4.—Post-larval *Pleuronectes microcephalus*, 12 mm. long. Right eye seen through from left side.

with *Temora longicornis* and *Podon* (probably *intermedius*). *Temora*, as many as 6 in one individual, occurs in 51 out of 221 specimens, in all hauls except XVII and XXII (only one *Solea variegata* in the latter). They also are contained in the smallest (4 mm.) and the largest (11·5 mm.). A specimen of 4 mm. can swallow a *Temora* 1·5 mm. long. Other Harpacticids occurring rarely are *Longipedia Scotti* and *Microsetella norvegica*. *Oncæa* (cf. *media*) occurs fairly frequently, as many as 4 together, male and female, female the commonest. *Oncæa media* is a species not hitherto recorded from Plymouth; the length of the body is less than it is in *O. mediterranea* and *O. venusta* and the caudal furca are different. It occurs in 25 out of 221. *Corycæus anglicus* occurs rarely, *Acartia* (cf. *Clausi*) and *Pseudocalanus elongatus* occur once only, singly, and evidently not liked by the fish, as they certainly occur in the hauls and are taken by other young fish (e.g. *Scophthalmus*).

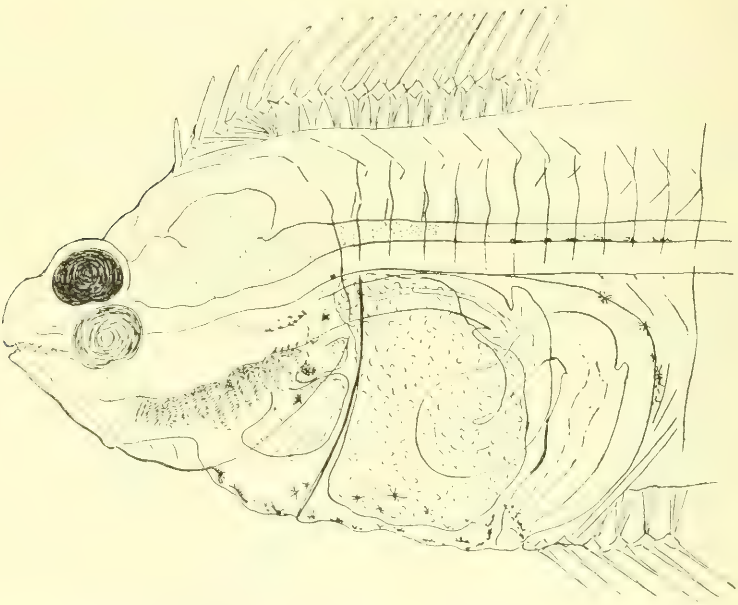


FIG. 5.—Post-larval *Pleuronectes flesus*, 10 mm. long. Right eye seen through from left side.

Podon intermedius occurs in 76, thus it is the form most frequently taken. It occurs in specimens from most of the hauls, in the smallest and also in the largest.

Balanus cypris stages occur in 9 specimens. Larval gastropods occur only occasionally. Besides the ova, minute organisms such as Infusoria, Peridiniales and diatoms occasionally occur, generally contained in diffuse masses, which may be from the alimentary canal of the Crustacea eaten. They apparently form an unimportant part of the diet. *Tintinnopsis ventricosa* is the only Infusorian, *Peridinium* sp. and *Prorocentrum micans* the only Peridinians and *Paralia sulcata*, *Navicula* sp. and *Pleurosigma* sp. occur among the diatoms, especially chains of *Paralia sulcata*. Small bodies, possibly spores, also occur.

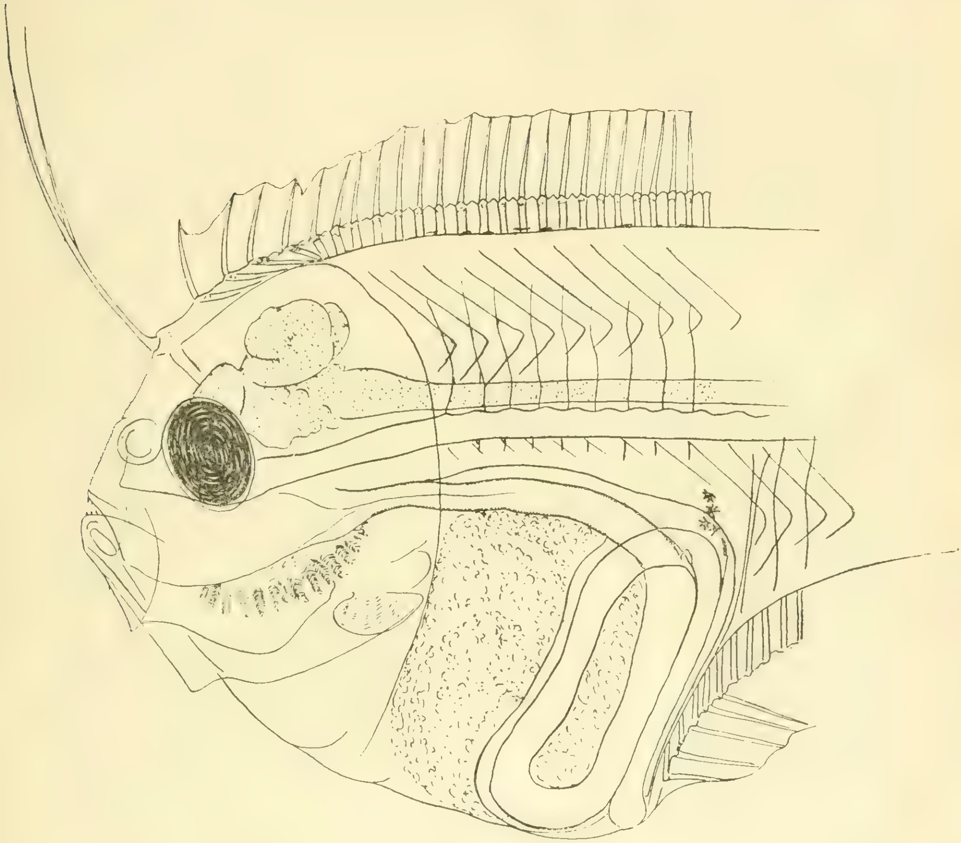


FIG. 6.—Post-larval *Arnoglossus laterna*, 12 mm. long.

Apparently the smallest and the largest specimens feed on the same kind of food, as no difference was found. Also in May and June the months when the hauls were taken, no difference is found. Although so few specimens of *Solea vulgaris* and *S. lascaris* were examined, the evidence seems to point to their taking the same kind of food as *S. variegata*.

PLEURONECTES LIMANDA L. Dab.

1353 specimens of the "Dab" were examined, preserved, from the Young Fish Trawl, 1914. These measured from 4 to 17 mm. in length. 416 contained no food, chiefly the smaller specimens; in those from 4 to 4·5 mm. no food could be detected, the food taken at this stage probably being very minute. Remains of small Copepods first occurred in those of 5 mm. Fairly large Copepods, such as *Temora*, occurred from 7 mm. upwards, but not in those of a smaller size. Nearly all the food recognized was Crustacea or ova.

Of the Crustacea recognizable *Podon* (cf. *intermedius*) was the commonest, occurring in 427. Those from Hauls V to X and XVII to XLVIII did not contain *Podon*, which looks as if *Podon* if present in numbers is preferred, but certain Copepods may be taken instead.

Copepods, Copepod nauplii, Copepod remains and fæces occurred in 382, Crustacea remains, indistinguishable, in 91. *Temora longicornis* is the commonest Copepod, occurring in 170 from 7 mm. long upwards. Other Copepods were Harpacticids in 52, 46 of which were *Euterpina acutifrons*, the others being unrecognizable. Other Copepods occurring rarely are *Pseudocalanus* (in 10), *Oncæa* (in 7), *Metridia lucens* (in 3) *Corycæus anglicus* (in 3). The only other Crustacea recognizable were the Cypris stages of *Balanus* in one specimen.

Ova occurred in 198 specimens, spores (?) in 10, larval Mollusks in 2. Diatoms, Peridinians, Infusoria and *Distephanus speculum* occurred occasionally. Diatoms in 13, 6 of which were *Paralia sulcata*, 1 *Pleurosigma* sp., 1 *Fragillaria* sp., 1 *Coscinodiscus* sp. The only Infusoria were *Tintinnopsis ventricosa* in 6. Two *Distephanus speculum* occurred in one of 6 mm. Kyle (1898) examined 30 out of 300 young Dabs measuring 10 to 16 mm., and found they only contained diatoms (*Coscinodiscus* and others) although Copepods were resent in the water. The present records certainly show that Crustace are taken earlier.

PLEURONECTES FLESUS L. Flounder.

Two fresh post-larval Flounders were examined from the tow-nettings, one from inside and one from outside the Breakwater in May. The first, 8·5 mm. contained nothing, the second, 10·5 mm. which occurred on May 31st, when the tow-nettings were full of the flagellate *Phæocystis*, had its alimentary canal full of *Phæocystis* spores. Forty-two preserved specimens from the Young Fish Trawl, 1914, were examined, 5·5 to 10·5 mm., 15 of which contained nothing, the rest diffuse remains almost certainly vegetable, one containing *Paralia sulcata* and *Fragillaria* sp. Not one contained any Crustacea remains, and here we have a very distinct difference between the Flounder and Dab and the various species of Solea. The gullet and stomach of the Flounder is long and narrow and the mouth small, which go with its method of feeding.

PLEURONECTES MICROCEPHALUS. Donov. Merry Sole.

Only one fresh specimen was obtained from the tow-nettings, West Channel in April, but it was very small, 4 mm. with yolk sac and no food.

247 preserved specimens from the Young Fish Trawl, 1914, were examined, 5·5 mm. to 18·5 mm. Of these 195 contained no food, 35 contained ova ; only one Copepod was distinguished, *Euterpina acutifrons*, in a specimen 10 mm. long. *Podon* (cf. *intermedius*) occurred in 3, 8·5 to 10 mm. long. Sixteen contained remains of Crustacea, 5 of which were recognizable as remains of small Copepods. One *Peridinium* sp. occurred and diatoms (*Navicula* and *Pleurosigma*) occurred in 3.

Thus the food of the "Merry Sole" is much more like that of the Flounder, than of the Dab and Sole, and its mouth and alimentary canal are of the small and narrow type which seems to go with a vegetarian diet, or at any rate a diet of small and soft organisms other than Crustacea.

ARNOGLOSSUS SP. (Walb.).

These are chiefly *A. laterna*. 288 specimens, preserved, were examined from the Young Fish Trawl, 1914, 3·5 to 22·5 mm. long. Nearly all the smaller specimens were from the early hauls (XIII to XXXVI). Most of the larger specimens being from the later hauls (XLII to LXXXIII). The alimentary canals of all the small specimens up to 8 mm. (except one ovum in a specimen of 5 mm.) were empty ; one of 8·5 mm. contained *Pseudocalanus*, but with that single exception those measuring 8·5 to 10 mm. were empty. From 10·5 mm. to 22·5 mm. some specimens contained Copepods, but very many were empty. 241 out of 288 were empty, and of these 208 were from the early hauls in which only 3 contained anything, one of 5 mm. containing an ovum, and 2 specimens of 14 mm. in Haul XXXVI containing *Pseudocalanus*, which is the earliest appearance of a Copepod in any of the specimens. Twenty-five contained Copepods, 18 of which were *Pseudocalanus* (as many as 15 in one specimen 19·5 mm. long), one contained *Paracalanus parvus* and one *Euterpina acutifrons*. From this it seems that the smaller specimens do not eat Copepods and the larger specimens only eat the small species. Only a very few diatoms occurred, *Paralia sulcata* once and *Navicula* spp. in the Copepod fæces. Here again we have with the small mouth and narrow gullet and stomach an absence of Crustacea food in the young and only small Copepods in the older forms.

RHOMBUS MAXIMUS L. TURBOT.

Two specimens were examined fresh from tow-nettings from within and outside the Breakwater in August, 11·5 and 14 mm. The first contained 15 *Temora longicornis*, the second 2 *Balanus nauplii* and 3 *Centropages typicus*. One preserved specimen (mounted) from the Young Fish Trawl was too much pigmented for the food to be distinguishable.

RHOMBUS LÆVIS RONDEL. BRILL.

Two specimens were examined fresh from the tow-nettings within and outside the Breakwater in July and August, 14 and 18 mm. long. The first contained Copepod remains indistinguishable, the second contained 7 *Temora longicornis*, 3 *Centropages typicus*, 3 *Brachyura* zoeæ, 9 *Hippolyte* larvæ and a Nematode probably parasitic. Five preserved specimens from the Young Fish Trawl, 1914, were also examined, all of which contained *Podon* (cf. *intermedius*) and one also contained *Centropages*. Cunningham (1890) found that young Brill of 2·2 to 2·5 cm. ate the young Flounders of 12 mm. and he thinks that they probably naturally prey upon young fish at that stage, when they are nearly completely metamorphosed.

Both the young Turbot and Brill have a very large mouth with a thick gullet and wide stomach.

ZEUGOPTERUS PUNCTATUS (BL.).

Thirty-five specimens examined, preserved, from the Young Fish Trawl, 1914, 5 to 10·5 mm. long. The smallest contained ova, but at 6 mm. a specimen contained 4 adult *Temora longicornis*. They appear to feed very much like *Solea*, 23 contained *Temora*, 10 contained *Euterpina acutifrons*, 2 contained *Oncæa* (cf. *media*). *Calanus finmarchicus* occurred in one and *Metridia lucens* in one. Ova were frequent. A good many of the Copepod remains were indistinguishable.

ZEUGOPTERUS UNIMACULATUS (RISSO).

Fifteen specimens, preserved, were examined from the Young Fish Trawl, 1914, 4·5 to 9·5 mm. long. The food content was not easily seen, but all except 2 contained Crustacea. One of 4·5 mm. contained remains of Crustacea but indistinguishable. *Temora longicornis* occurred in 3, *Euterpina acutifrons* in one, *Podon* (cf. *intermedius*) in 3. *Paracalanus parvus* and *Pseudocalanus elongatus* occurred in one specimen.

These two Zeugopterus have large mouths and short and thick gullets and the food is much like *Solea* and *Pleuronectes limanda.*

SCOPHTHALMUS NORVEGICUS (Gthr.).

404 specimens, preserved, were examined from the Young Fish Trawl, 1914, 3·5 to 12 mm. long. There were only 2 of 12 mm. and neither of them contained any food. Thirty-six contained nothing, 34 contained ova only, two were indistinguishable and the rest contained Crustacea, chiefly Copepods, *Podon* occurring in several. Copepod remains which were indistinguishable were in 55 specimens of all sizes. The smallest (3·5 mm.) contained Copepod remains (probably *Pseudocalanus*) so as *Scophthalmus norvegicus* hatches at about 2·5 mm. it must take Copepod food almost directly. A specimen 4 5 mm. long contained a *Metridia lucens* 2 mm. long. One of 4 mm. contained a *Paracalanus parvus*, so there is no evidence that the smaller specimens eat anything different from the larger specimens, the same sort of food being found in all of them in these samples. A very few contained diatoms (*Paralia sulcata* and *Navicula* sp.), which very likely come from the alimentary canal of the Copepods. One specimen of 4 mm., which contained Copepod remains, contained also *Peridinium ovatum, Prorocentrum micans* and remains of other Peridinians. One contained *Tintinnopsis ventricosa.* Spores occurred once. Much more food was found in the specimens from Hauls X to XVI and little food in those from the later hauls.

Ova occurred in 34 specimens without anything else and in 65 specimens altogether. They are more abundant from the later hauls. Apparently when many Copepods are eaten these are not taken so much. All sizes eat them, but they are commonest in the smaller specimens of from 4 to 5·5 mm.

Copepods are evidently the favourite food and are found in 334 specimens. The favourite is certainly *Pseudocalanus elongatus*. which occurs in 158 specimens, as many as 6 at once and in all sizes from 4 to 11·5 mm., one of 3·5 mm. probably containing it also. It is very abundant, especially from Hauls X to XVI, absent from XVIII to XXVI.

The next favourite is *Metridia lucens*, which occurs in 75 specimens, up to 3 in one specimen, in all sizes from 4·5 mm. upwards, in the same hauls as *Pseudocalanus elongatus.* Next come *Acartia* (cf. *Clausii*) in 49, *Oncœa* (cf. *media*) in 26, *Paracalanus parvus* in 25, *Euterpina acutifrons* in 20, *Temora longicornis* in 6 only, and *Temora* nauplii in 4. *Calanus finmarchicus* (juv.) in 2 and *Corycæus anglicus* in one.

It is thus seen that a variety of Copepods is taken, but *Pseudocalanus* markedly predominates.

Seventy-one specimens were in Haul X and these contain almost entirely Copepods, chiefly *Pseudocalanus* and *Metridia, Acartia* also being fairly frequent. *Euterpina* and *Oncæa* not common and *Podon* occurs a few times, *Temora* only once. Comparing this with *Solea variegata* from the same haul we find *Solea* has chiefly eaten *Temora* and *Podon*, so that selection of food must take place. It is the same in Hauls XI, XII and XIII. In XIII *Pleuronectes limanda* has also selected chiefly *Podon* and a few *Temora*. In Haul XVII large Copepods seem rare and in XXIII the fish have eaten little.

GADIDÆ.

The Whiting, *Gadus merlangus*, is the commonest gadoid in the townettings, the Pouting, *G. luscus*, coming next. From the Young Fish Trawl a number of *G. merlangus* and *G. minutus* were examined, the Whiting not showing the food well in the preserved material. *Pseudocalanus* appears to be the favourite food of all the post-larval gadoids except the very young specimens.

GADUS MORRHUA L. Cod.

Only one specimen from inside the Breakwater, fresh from the townettings in May, 19 mm. This contained one *Calanus finmarchicus* and one *Temora longicornis*.

GADUS MERLANGUS L. Whiting.

Twenty-seven specimens examined fresh from the tow-nettings, April to July, from both inside and outside the Breakwater, from 4 to 34 mm. The first obtained on April 2nd and 4th were 4 mm. long ; one had nothing inside, the other had 2 nauplii of *Calanus finmarchicus* and one *Coscinodiscus Granii ;* one of 2·5 mm. ca. contained no food, but one of 3 mm. contained Copepod remains. The rest, excepting 3 which were empty, contained Copepod remains, of which 11 contained *Pseudocalanus elongatus* (from 1 to 3), 2 contained *Paracalanus parvus* and the rest were indistinguishable. The specimen of 34 mm. contained indistinguishable Copepods.

At 4 mm. nauplii are eaten and at 5 mm. full-sized *Pseudocalanus.*

171 preserved specimens from the Young Fish Trawl, 1914, were also

examined, but the contents were very difficult to identify. Size 6 to 11·5 mm., 49 contained nothing, 7 contained only ova, 2 contained *Evadne*. and the remainder contained Copepods. Except one *Oncœa*, all those identified were *Pseudocalanus*, and those not identified were probably *Pseudocalanus*.

GADUS LUSCUS L. Pouting.

Sixteen small specimens were examined fresh from the tow-nettings from both within and outside the Breakwater, from January to April, 1·5 to 7 mm. long. In October 2 more were obtained and one in November. The yolk sac was present in those up to 2·5 mm., and these contained no food, 2 of 3 mm. contained nothing, 2 contained green food remains and one (from the region of the Knap Buoy) contained a *Coscinodiscus* and a *Coccosphæra* sp. (cf. *atlantica*) in perfect condition. In October one of 4 mm. contained a *Pseudocalanus elongatus* and one of 7 mm. contained 2 *Pseudocalanus*. one *Acartia clausi* and one live *Calanus finmarchicus* just swallowed, with its tail sticking out of the mouth, apparently having been caught after the fish had been captured.

From the small amount of material available it would appear that the character of the food is changed at about 4 mm., those of a smaller size eating microscopic food and after that changing to a Copepod diet.

GADUS POLLACHIUS L. Pollack.

Eleven preserved specimens from the Young Fish Trawl, 1914, were examined, 5·5 to 24 mm. The smallest contained Copepod remains. 2 contained nothing and the rest Copepods mostly indistinguishable, but 3 contained *Acartia* (cf. *Clausi*) and one *Temora longicornis* and *Euterpina acutifrons*.

GADUS MINUTUS O. F. Müll. Bib.

140 preserved specimens from the Young Fish Trawl, 1914, were examined, from 6 to 14 mm. Of these 4 contained nothing, one contained ova, one a *Dinophysis* sp. and all the rest contained Copepods. 6 of which were indistinguishable, but all the rest contained *Pseudocalanus elongatus*. *Podon*, *Acartia*, *Euterpina* and *Metridia* each occurred once with *Pseudocalanus*. It is quite evident that *Pseudocalanus* is the favourite food of *Gadus minutus* and it occurs in those of all sizes examined.

ONOS MUSTELA L. Rockling.

Thirteen fresh specimens from the tow-nettings were examined, from both inside and outside the Breakwater, from 2 to 26 mm. long, from March to August. The small ones below 3 mm. had a yolk sac and contained no food, but in one of 3 mm. 2 *Temora* nauplii were present. One of 5 mm. contained ova and one of 5·5 mm. *Temora* nauplii, 2 of the others contained nothing and the rest contained indistinguishable Copepod remains.

AMMODYTES TOBIANUS L. Lesser Sand Eel.

Twelve specimens were examined fresh from the tow-nettings from both inside and outside the Breakwater, from 4·5 to 6·5 mm. from February to March and again in October. The smallest contained no food, but those from 5 mm., except one which was empty, all contained green food remains.

AMMODYTES LANCEOLATUS Lesaur. Larger Launce.

Thirty specimens were examined fresh from the tow-nettings from both inside and outside the Breakwater, from 7 to 14 mm., from July to October. Twenty-one contained no food, one of 8 mm. contained green food remains, the rest contained Copepods, 4 indistinguishable, *Acartia clausi*, *Pseudocalanus elongatus*, *Oithona* sp. and Copepod nauplii being recognized. One of 10 mm. contained Copepod nauplii and 5 *Rhizosolenia Shrubsolei*, the only time that diatom was seen in a fish.

GASTEROSTEUS SPINACHIA L. 15-Spined Stickleback.

Three 15-spined Sticklebacks were examined fresh from the tow-nettings, from among Zostera, both inside and outside the Breakwater in August and September, 7·5 to 8·5 mm. Two contained no food, the other contained remains of Amphipods and many Harpacticids.

SYNGNATHUS ACUS L. Greater Pipe Fish.

Five specimens were examined fresh from the tow-nettings from among the Zostera from both inside and outside the Breakwater, August to October, 2·5 to 6·5 cm. long. One contained nothing, one contained remains of *Temora* nauplii and *Pseudocalanus elongatus*, one contained 9 *Centropages typicus*, one contained many *Pseudocalanus*, one *Temora*, 2 *Acartia Clausi*, one *Corycæus anglicus* and the remains of *Centropages typicus*, the last contained 2 *Temora*, 4 *Centropages typicus*, many *Pseudocalanus* and 2 *Paracalanus parvus*.

SYGNATHUS ROSTELLATUS Nilss.

Three specimens examined fresh from the tow-nettings, from among Zostera, both inside and outside the Breakwater, August and September, 4·5 to 10·5 cm. Two contained remains of Decapods, the third contained 3 crab zoeæ, one Acartia sp., 8 *Pseudocalanus elongatus* and other Crustacea remains.

NEROPHIS LUMBRICIFORMIS Yarr.

Three specimens examined fresh from the tow-nettings from both inside and outside the Breakwater, August and October, 10 to 40 mm. 2 contained nothing, the third a young Copepod and 3 Copepod nauplii.

The young begin to feed almost at once. A male with eggs from Wembury was put in a glass jar and kept at a uniform temperature by immersing in a tank and the eggs hatched. Plankton was given at once, and after the first day, when a large yolk sac was present, the little fish ate *Halosphæra viridis*, larval Mollusks and small Copepods.

CLUPEA HARENGUS L.

1795 larval and post-larval Herrings were examined fresh from the tow-nettings, from both inside and outside the Breakwater, from January to March and again in October, measuring 5·5 to 18 mm. The yolk sac was present in all those from 5·5 to 8 mm., but it may remain up to 12 mm. in exceptional cases. However, even with the yolk present, from 7 mm. food may be taken. The yolk seems to stay longer in some lots, as though there were a shortage of food in certain areas with a consequent lengthening of time in keeping the yolk. The smallest specimen with any food inside measured 7 mm., and that was only green food remains. At 8 mm. Harpacticids may be taken and larval Mollusks.

On January 30th, 589 specimens from 7 to 12 mm. (mostly 7 to 10 mm.) were taken and all of these, except one of 12 mm., contained no food, the exception containing one *Euterpina acutifrons*. Those measuring from 7 to 10 mm. all had the yolk sac still present. On February 1st another lot of 431, measuring from 8 to 10 mm. all had the yolk sac still present except one of 10 mm., but 35 contained food, 16 of these containing larval gastropods, 2 larval bivalves, 12 green food remains, one a Harpacticid, one a Copepod nauplius, one 2 Peridinians (*Prorocentrum micans* and

(*Gonyaulax spinifera*), one a diatom (*Paralia sulcata*). Green food remains are in the smallest, then larval Mollusks, Copepods coming next. On February 6th, 120 specimens taken are much like the last, even those 11 mm. long. Most of them contain no food, but green food, larval gastropods, larval bivalves, *Temora* nauplii, ova and Harpacticids were present. On February 9th it is the same sort of thing, but on February 13th, when evidently the *Balanus* nauplii had just appeared, they were taken by several of the young herring. Out of 234 specimens from 7 to 12·5 mm. long, most of those above 8 mm. had lost the yolk, 46 contained *Balanus nauplii*, 2 contained *Pseudocalanus elongatus*, 4 contained *Euterpina acutifrons*, one contained *Oithona similis*, several contained larval gastropods, larval bivalves and green food remains. It seems that with the coming of abundance of food the yolk sac disappears much earlier. On February 22nd *Balanus* nauplii were again frequently eaten. *Oncaea* sp. once, *Evadne Nordmanni* once (peculiarly early for this Cladoceran). Up to March 15th the same kind of food is present and then the Herrings stop, not appearing again until October 17th, when from that date to the middle of December they were caught in small numbers measuring from 8 to 18 mm. but not containing any food.

The earliest caught Herring, January 10th to 23rd, were further advanced than those taken late in January and early in February. Several from 9·5 to 13 mm. containing *Euterpina acutifrons*, *Pseudocalanus elongatus* (one of 12 mm. containing 5 *Pseudocalanus*), *Oithona similis*, *Corycæus anglicus* and Copepod nauplii, *Pseudocalanus* being the most frequent.

A few contained sand grains, others diatoms amongst which were *Campylodiscus* sp., *Hyalodiscus stelliger*, *Coscinodiscus* sp. and *Paralia sulcata*. The flagellate *Halosphæra viridis* was contained in 3, and possibly spherical bodies sometimes present are *Halosphæra*. The frequent presence of sand grains and the character of the diatoms, which are all bottom forms although often present in the plankton, suggests that the young herring sometimes feeds on the bottom.

From the above records it is seen that the larval herring eats before the yolk sac has gone, the earliest food being green food, afterwards larval Mollusks, both gastropods and bivalves, small Copepods and Copepod nauplii, Balanus nauplii and occasional diatoms and *Halosphæra viridis*. This agrees well with records by H. A. Meyer (1880) when feeding young Herring reared artificially. He found the greenish matter, larval gastropods and bivalves, Copepods and nauplii, the Copepod diet increasing as the fish grew. McIntosh (1889) has also noticed the green food remains in the very young Herring.

CLUPEA SPRATTUS L.

164 specimens were examined fresh from the tow-nettings, from both inside and outside the Breakwater, from January to May and from July to November, the bulk from January to April, measuring 3 to 27 mm. Those from 3 to 4 mm. have no eye pigment, a large yolk sac and no food. From 4·5 mm. the eye is pigmented and, although yolk may still be present, green food remains occur and also in the larger specimens. A spherical body which may be *Halosphæra* was present in one. From 4·5 mm. and upwards the yolk sac disappears, but green food remains are still present, probably from diatoms, as 6 *Thalassiothrix nitzschioides* were present in one of 5 mm. Not until July, in a specimen of 8 mm., is any crustacean food present, and this specimen contained 2 *Temora* nauplii

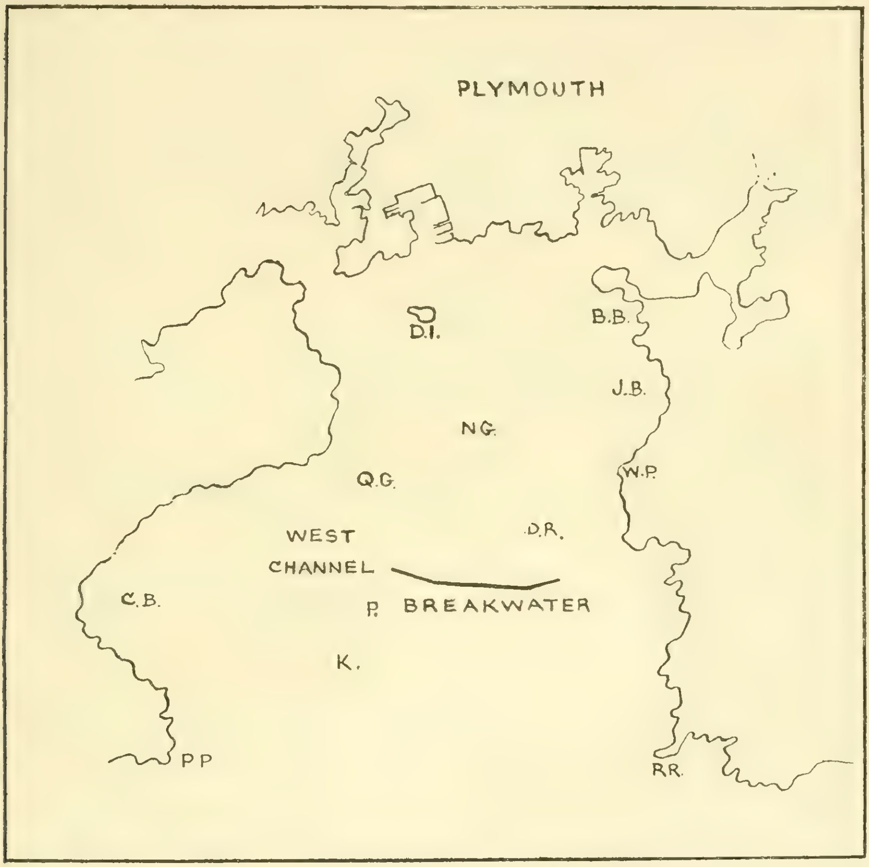


FIG. 7.—Plan of Plymouth Sound. B B = Batten Bay. C B = Cawsand Bay. D I = Drake's Island. D R = Duke's Rocks. J B = Jennycliff Bay. K = Knap Buoy. N G = New Grounds. Q G = Queen's Grounds. P = Panther Buoy. P P = Penlee Point. R R = Reny Rocks. W P = White Patch.

in addition to green food remains. On October 3rd a specimen of 27 mm. contained 2 *Pseudocalanus elongatus.*

It thus appears that green vegetable food is taken chiefly, although at 8 mm. small Crustacea may be eaten. An examination of preserved material showed poor results, although *Pseudocalanus* was present in a few specimens and also larval Mollusks. A. Scott (1906) records *Pseudocalanus elongatus* from 2 Sprats of 15 mm., so it is evidently a favourite food of the larval Sprat.

The tow-nettings were taken with ordinary coarse and medium nets, and sometimes with a bigger net, which although not giving much better results, caught the fish from the Zostera, which evidently were feeding there. These included *Rhamphistoma belone,* various pipe fish and *Cyclopterus lumpus.* A small plan is given showing the various localities from which the tow-nettings were taken. (Fig. 7.)

LITERATURE.

1917. *Allen, E. J.* Post-Larval Teleosteans collected near Plymouth during the summer of 1914. Jour. Mar. Biol. Assoc., N.S., Vol. XI, 2.

1890. *Cunningham, J. T.* Notes on Recent Experiments relating to the Growth and Rearing of Food Fish at the Laboratory. J.M.B.A., N.S., Vol. I, p. 367.

1897. *Dannevig, H.* On the Rearing of the Larval and Post-Larval Stages of the Plaice and other Flat-Fishes. 15th Ann. Rep. of the Fishery Board for Scotland.

1898. Ibid. 16th Annual Report.

1882. *Forbes, S. A.* The Food of the Young Whitefish (*Coregonus clupeiformis*). Bull. U.S. Fish Com., I, pp. 19 and 269.

1884. Ibid. p. 770.

1893. *Herdman, W. A.* Report of the Lancashire Sea Fisheries Laboratory.

1898. *Herdman, W. A.* Report of the Lancashire Sea Fisheries Laboratory.

1912. *Herdman, W. A.* Report of the Lancashire Sea Fisheries Laboratory.

1905. *Holt, E. W. L.*, and *Byrne, L. W.* Figures and Descriptions of the British and Irish Species of *Solea*. Report on the Sea and Inland Fisheries of Ireland for 1902–3.

1898. *Kyle, H.* The Post-larval Stages of the Plaice, etc. 16th Rep. Fish. Board for Scotland.

1889. *McIntosh, W. C.* On the Pelagic Fauna of the Bay of St. Andrews. 7th Report of the Fishery Board for Scotland for the year 1888.

1880. *Meyer, H. A.* Biological Observations made during the Artificial Rearing of Herrings in the Western Baltic. Report of the U.S. Fish Commission for 1878.

1894. *Petersen, C. G. J.* On the Biology of our Flat-Fishes, and on the Decrease of our Flat-Fish Fisheries.
Report of the Danish Biological Station for 1893.

1917. On the Development of Our Common Gobies (Gobius) from the Egg to the Adult Stages. Ibid. for 1916.

1898. *Scott, A.* Observations on the Habits and Food of Young Fishes. Lancashire Sea Fisheries Report for 1898.

1906. —— Notes on the Food of Young Fishes. Ibid. 1906.

RECORD OF LARVAL AND POST-LARVAL FISH FROM THE TOW-NETTINGS.

Date.	Locality.	Fish.	No.	Size in mm.	Food present.
Jan., 1917					
10	West end of Breakwater	Clupea harengus	15	9·5–11·5	*Oithona similis, Pseudocalanus elongatus, Euterpina acutifrons, Copepod* nauplii, larval bivalves.
	Knap	,,	8	11–12	*Pseudocalanus elongatus, Euterpina acutifrons, Corycæus anglicus,* young Harpacticids.
16	Off White Patch	,,	2	10·5–11	*Pseudocalanus elongatus.*
		Gadus luscus	1	7	*Pseudocalanus elongatus.*
	West end of Breakwater	Clupea harengus	5	11·5–12	No food.
	West Channel	,,	4	10–12	*Pseudocalanus elongatus.*
	Knap	,,	2	5·5–12	No food.
18	West Channel	,,	10	5·5–13	*Pseudocalanus elongatus.*
	Off White Patch	,,	3	5·5–12	*Oithona similis.*
		Clupea sprattus	1	3·5	No food.
	Breakwater	Clupea harengus	5	9–14	Copepod remains.
	New Grounds	,,	14	6–13	*Pseudocalanus elongatus,* Harpacticids, Copepod nauplii.
	Knap	,,	4	10–13	*Pseudocalanus elongatus, Oithona similis, Euterpina acutifrons.*
		Clupea sprattus	5	3·5–3·6	No food.
23	Batten Bay	Gadus luscus	1	4	,,
		Clupea harengus	1	11·5	,,
	Off White Patch	,,	2	9–12	,,
	Inside Breakwater	,,	2	11	,,

Date. Jan.	Locality.	Fish.	No.	Size in mm.	Food present.
30]	Inside Breakwater	Clupea harengus	205	7–12	*Euterpina acutifrons.*
		Clupea sprattus	1	4–4·5	No food.
	Off White Patch	,,	7	3–6	Green food remains.
		Clupea harengus	112	7–10·5	No food.
	Jennycliff Bay	,,	41	7–10·5	,,
	West Channel	,,	231	6–9	,,
		Clupea sprattus	5	4–5	Green food remains.
Feb. 1	West Channel	Clupea harengus	147	8–10	Larval gastropods, green food remains.
		Clupea sprattus	3	3·2–5·5	No food.
	Off White Patch	,,	2	4	,,
		Clupea harengus	284	8–11	Green food remains, larval gastropods, larval bivalves, *Paralia sulcata*, Harpacticids, *Prorocentrum micans*, *Gonyaulax spinifera*, Copepod nauplius.
6	Jennycliff Bay	,,	41	9–12	Larval gastropods, *Temora* nauplius.
	Batten Bay	,,	29	9–11	Larval gastropods
		Clupea sprattus	1	3·5	No food.
	Middle of Breakwater	Clupea harengus	16	9–12	Larval gastropods.
	Breakwater	,,	34	10–12	Green food remains, larval gastropods, *Temora* nauplii.
9	New Grounds	,,	79	7–10	Green food remains, larval gastropods.
		Cottus bubalis	1	5	No food.
	White Patch	Clupea harengus	54	7–10	Larval gastropods, ova, green food remains.
		Clupea sprattus	3	4	No food.
	Jennycliff Bay	Clupea harengus	45	8–10	Larval gastropods, ova.
13	West Channel	,,	56	7–12·5	*Pseudocalanus elongatus*, *Euterpina acutifrons*, Copepod remains, *Balanus* nauplii, green food remains, larval gastropods, larval bivalves, *Halosphæra viridis*, *Coscinodiscus radiatus*.
		Clupea sprattus	4	4·5–5	Green food remains.
	Breakwater	,,	1	5·5	,, ,, ,,
		Clupea harengus	69	7–11·5	Green food remains, *Balanus* nauplii, larval gastropods, larval bivalves, *Campylodiscus* sp.
	Off White Patch	,,	30	8–11	*Balanus* nauplii, larval bivalves, ova, green food remains.
		Clupea sprattus	1	3·5	No food.
		Cottus bubalis	1	5	Crustacea remains.
		Gobius sp.	1	3·5	No food.
	Jennycliff	Clupea harengus	88	8–12	Green food remains, *Balanus* nauplii, ova, larval gastropods, larval bivalves, *Euterpina acutifrons*, *Hyalodiscus stelliger*.
		Clupea sprattus	1	4·5	No food.

Date.	Locality.	Fish.	No.	Size in mm.	Food present.
Feb.					
20	Off White Patch	Clupea harengus	6	10–12·5	*Balanus* nauplii.
	Duke's Rock	,,	20	9–12·5	*Balanus* nauplii, ova.
	Jennycliff Bay	,,	2	11	No food.
	New Grounds	,,	19	8·5–14	*Balanus* nauplii, Copepod nauplii, larval gastropods.
22	Knap	,,	35	9–12	Green food remains, larval gastropods, larval bivalves, *Balanus* nauplii, *Oncæa* sp., *Coscinodiscus* sp., *Hyalodiscus stelliger*.
		Clupea sprattus	4	4·5–5	Green food remains.
		Agonus cataphractus	1	8·5	No food.
	Panther	Clupea harengus	32	8–10	Green food remains, *Balanus* nauplii, larval gastropods, larval bivalves.
		Clupea sprattus	1	5	Green food remains.
	Penlee	,,	1	5	No food.
		Clupea harengus	12	8–10·5	*Balanus* nauplii, larval gastropods, *Evadne nordmanni*.
	Cawsand	,,	8	10–13·5	*Balanus* nauplii, larval bivalves, *Halosphæra viridis*.
27	Panther	Clupea harengus	2	8·5–10	*Balanus* nauplii, green food remains.
		Clupea sprattus	8	3·5–5	Green food remains.
		Cottus bubalis	1	5	*Balanus* nauplii.
	Breakwater	Clupea sprattus	5	3–5	Green food remains.
		Ammodytes tobianus	2	4·5	No food.
	Off White Patch	Clupea harengus	1	8·5	,,
		Clupea sprattus	5	3–5	Green food remains.
		Gobius sp.	1	3·5	,, ,, ,,
March.					
1	Off White Patch	Clupea sprattus	1	5	Green food remains.
	Breakwater	,,	1	3·5	No food.
		Clupea harengus	1	10	,,
	Knap	Clupea sprattus	2	4	,,
		Ammodytes tobianus	1	4·5	Green food remains.
	Panther	Clupea harengus	1	6	No food.
		Clupea sprattus	4	4·5	,,
	Batten Bay	,,	1	5	Green food remains.
		Clupea harengus	1	9	No food.
12	Breakwater	Clupea sprattus	3	5	Green food remains.
		Cyclogaster Montagui	1	4 ca.	Crustacea remains.
		Ammodytes tobianus	2	4·5–5·5	Green food remains.
		Cottus bubalis	2	4·5	No food.
	Knap-Penlee	Clupea harengus	1	11	*Balanus* nauplii, larval bivalve.
	West Channel	Clupea sprattus	5	3–5·5	Green food remains.
		Ammodytes tobianus	1	4·5	,, ,, ,,
	Off White Patch	,, ,,	1	4·5	,, ,, ,,
		Cottus bubalis	1	5	,, ,, ,,
15	Panther	Ammodytes tobianus	1	5·5	,, ,, ,,
		Cottus bubalis	1	4·5	,, ,, ,,
		Clupea harengus	3	10·5–11	No food.
		Gobius sp.	2	2·5–3	,,
		Callionymus lyra	1	2 ca.	,,
	Knap	Cottus bubalis	3	5	*Balanus* nauplii.
		Gobius sp.	5	3–3·5	No food.
		Ammodytes tobianus	1	5·5	,,
		Clupea sprattus	1	3·6	,,

Date. March.	Locality.	Fish.	No.	Size in mm.	Food present.
15	Off White Patch	Clupea sprattus	1	4	No food.
		Cottus bubalis	3	5–5·5	*Balanus* nauplii, Crustacea remains.
		Gobius sp.	1	4	No food.
		Ammodytes tobianus	1	6·5	Green food remains.
	Breakwater	Clupea sprattus	1	9	No food.
19	Off White Patch	,,	1	3	,,
		Cottus bubalis	1	5 ca.	*Balanus* nauplii.
	New Grounds	Clupea sprattus	10	3·5–7	Green food remains.
		Callionymus lyra	3	1·5	No food.
		Gadus luscus	7	2–3	Green food remains.
	Breakwater	,,	1	2·5	No food.
		Clupea sprattus	1	4·5	,,
27	Breakwater	,,	5	4·5–7	Green food remains.
		Onos mustela	1	2·5	No food.
30	New Grounds	Clupea sprattus	10	4–6	Green food remains.
		Agonus cataphractus	1	7	*Coscinodiscus excentricus.*
		Gadus luscus	1	1·5	No food.
		Callionymus lyra	1	2 ca.	*Paralia sulcata*, *Coscinodiscus excentricus.*
	Breakwater	Clupea sprattus	19	4–6·5	Green food remains.
		Gadus luscus	2	1·5–2	No food.
		Gobius sp.	5	2–3	Green food remains, larval bivalve, *Coscinodiscus* sp.
		Cottus bubalis	5	4·5–5	*Balanus* nauplii, *Biddulphia regia*, *Biddulphia* sp., *Coscinodiscus Granii*, larval gastropods, *Coscinodiscus radiatus*, *Thalassiosira gravida*, Copepod remains.
		Callionymus lyra	1	1·5	*Coscinodiscus* sp.
		Onos mustela	1	2·5	No food.
April.					
2	Knap	Clupea sprattus	2	4·5–5	Green food remains.
		Callionymus lyra	2	2·5	Green food remains, *Navicula* sp., *Pleurosigma* sp., *Coscinodiscus* sp.
		Cyclogaster Montagui	1	4·5	No food.
		Gadus merlangus	1	4	,,
		Gadus luscus	1	3	*Coccosphæra* sp. (cf. *atlantica*), *Coscinodiscus* sp.
4	Breakwater	Clupea sprattus	9	4·5–6	Green food remains.
		Gadus merlangus	1	4 ca.	Nauplii of *Calanus finmarchicus*, *Coscinodiscus Granii.*
		Cyclogaster Montagui	1	3·5	No food.
12	Queen's Grounds	Gobius sp.	2	3·5–4	*Balanus* nauplii.
		Clupea sprattus	1	5·5	Green food remains.
		Callionymus lyra	1	2·5	No food.
		Zeugopterus (?) sp.	1	7	,,
	Duke's Rock	Gobius sp.	3	2·5–3·5	Green food remains.
		Gadus merlangus	2	2·5–5	*Pseudocalanus elongatus.*
		Callionymus lyra	1	1·5 ca.	No food.
		Cyclogaster Montagui	1	4	Brownish food remains.
18	N.E. of Drake's Island	Callionymus lyra	1	3·6	No food.
		Clupea sprattus	1	7	,,

Date.	Locality.	Fish.	No.	Size in mm.	Food present.
April					
23	Breakwater	Gadus merlangus	3	7·5–9	*Pseudocalanus elongatus* and eggs.
		Cottus bubalis	1	10	Nothing.
	Duke's Rock	Callionymus lyra	4	3·5–5	Copepod nauplii.
		Gadus merlangus	3	8–8·5	*Paracalanus parvus.*
		Onos mustela	1	4·5	Copepod nauplii remains.
	West Channel	Cottus bubalis	1	7	*Temora longicornis.*
		Pleuronectes microcephalus	1	4	No food.
25	Knap	Onos mustela	1	3·5	,,
		Gadus merlangus	1	7·5	*Pseudocalanus elongatus* and eggs.
30	Knap	Callionymus lyra	2	3-4	No food.
	S. of Knap	,,	1	4·5	,,
May.					
4	West of Breakwater	Gadus merlangus	2	10–11	*Pseudocalanus elongatus.*
10	Cawsand Bay	,,	2	6–12	,, ,,
		Gobius sp.	1	2·5	No food.
		Callionymus lyra	4	2–3·5	Copepod remains.
	Inner Knap	,,	5	2·5–5·5	,, ,,
		Gadus merlangus	7	3–14	*Pseudocalanus elongatus*, Copepod remains.
		Pleuronectes flesus	1	8·5	No food.
24	Breakwater	Clupea sprattus	1	24·5	,,
		Gadus morrhua	1	19	*Calanus finmarchicus*, *Temora longicornis.*
		Gadus merlangus	3	6–7·5	Copepod remains.
		Onos mustela	3	5–11	Copepod remains, ova.
		Callionymus lyra	2	3	No food.
	West Channel	,,	2	4	,,
31	Breakwater	Pleuronectes flesus	1	10·5	*Phæocystis* spores.
	Knap	Gobius sp.	1	4	No food.
June					
7	Off Reny Rocks	Callionymus lyra	1	5	No food.
12	Knap	,,	1	7	,,
	Breakwater	,,	1	5·5	,,
	West Channel	Trigla gurnardus	1	8	*Podon intermedius.*
		Gobius sp.	1	5	No food.
		Labrus bergylta	2	2·5	,,
July.					
2	Knap	Callionymus lyra	1	3	*Euterpina acutifrons.*
		Clupea sprattus	1	5	No food.
	Panther	Lophius piscatorius	1	8·5	,,
4	W. End of Breakwater	Clupea sprattus	1	7	,,
9	Off White Patch	Gobius minutus	10	3·5–8	Nauplius of *Temora longicornis.*
		Callionymus lyra	2	2·5–4	No food.
		Ammodytes lanceolatus	1	10	Copepod nauplii, *Rhizosolenia shrubsolei.*
	West end of Breakwater	,,	1	7·5	No food.
		Gobius minutus	1	6	Copepod remains.
	Knap	,,	2	6–6·5	*Pseudocalanus elongatus*, Copepod remains.
11	White Patch	Callionymus lyra	1	3	No food.

Date. July	Locality.	Fish.	No.	Size in mm.	Food present.
11	White Patch	Labrus bergylta	1	6	*Cittarocyclis denticulata*, *Temora longicornis*, *Euterpina acutifrons*, Copepod indet., *Prorocentrum micans*, *Peridinium* sp., *Lithomelissa setosa*, *Tintinnopsis beroidea*.
	Knap	Callionymus lyra	2	7	*Balanus* nauplii.
23	Breakwater	Rhombus lævis	1	18	*Temora longicornis*, *Centropages typicus*. *Brachyura* zoæa, *Hippolyte* larvæ.
		Rhamphistoma belone	13	10–28	Green and brown food remains, *Harpacticus uniremis*, *Pleurosigma* sp. ova.
		Onos mustela	3	15–26	Copepod remains.
	Off White Patch	Gadus merlangus	1	34	,, ,,
	Panther	Rhamphistoma belone	2	12–17	Green food remains, *Harpacticus uniremis*.
		Cyclopterus lumpus	1	15	Amphipod remains, *Harpacticus uniremis*.
25	Panther	Clupea sprattus	1	5	No food.
		Gobius minutus	1	6	*Calanus* nauplii.
		Labrus bergylta	1	4·5	*Temora* nauplii, *Navicula* sp. Peridinian remains.
27	Knap	Lophius piscatorius	5	4–5	Copepod remains.
		Labrus bergylta	1	3	Green food remains.
		Onos mustela	1	3 ca.	*Temora* nauplii.
		Scomber scomber	3	3·5–4·5	Green food remains.
	Off White Patch	Labrus bergylta	3	2·5–4	*Temora* nauplii.
		Callionymus lyra	2	3–8	No food.
		Gobius minutus	1	4	Copepod nauplius remains.
	Breakwater	Labrus bergylta	2	2·5	Green food remains.
		Lepadogaster Candollei	1	4	No food.
30	Knap	,,	2	4·5–6	Copepod remains.
		Labrus bergylta	14	4–6	Green food remains, Copepod and Copepod nauplii remains.
		Callionymus lyra	1	8	Copepod remains.
		Onos mustela	1	6·5	,, ,,
		Scomber scomber	3	5–7	Brown and green food remains, Copepod nauplii.
	Panther	Scomber scomber	2	3–5	Brown and green food remains, Copepod nauplii.
		Labrus bergylta	7	4–6	Green food and Copepod nauplii remains.
		Onos mustela	1	6·5	Copepod remains.
		Callionymus lyra	1	7	,, ,,
August.					
1	Knap	Labrus bergylta	2	5	Copepod nauplii.
	Panther	,,	2	4–6	Young *Temora longicornis* and *Temora* nauplii.
		Scomber scomber	1	7	*Temora* nauplii.
7	Panther	Onos mustela	1	5·5	Young *Temora longicornis*.

Date. August	Locality.	Fish.	No.	Size in mm.	Food present.
10	Knap	Syngnathus acus	1	25	*Temora* nauplius remains, *Pseudocalanus elongatus.*
		Scomber scomber	4	3–4	Green food remains. Copepod nauplii, larval gastropods.
		Labrus bergylta	1	7	*Pseudocalanus elongatus.*
		Lepadogaster gouani	4	4–5·5	Copepod nauplii, Harpacticids indet.
		Lepadogaster Candollei	3	5–6·5	Young *Temora longicornis,* Copepod nauplius remains, Harpacticids indet.
	Panther	Labrus bergylta	1	7	*Temora longicornis.*
		Cyclopterus lumpus	1	18	Larval *Eupagurus,* Decapod larvæ remains.
13	West Channel	Lepadogaster Candollei	1	7·5	Copepod remains.
		Gobius sp.	1	11	Remains of diatoms, *Skeletonema costatum.*
	Breakwater	,,	3	12–13	Green food remains.
14	West End of Breakwater	,,	2	12	*Temora longicornis,* Balanus nauplus.
		Lepadogaster Candollei	1	8	Copepod remains.
		Blennius gattorugine	1	22	Remains of crab zoæa and Crangon larvæ.
15	Breakwater	Gobius sp.	1	11	No food.
		Gobius minutus	1	7	*Pseudocalanus elongatus.*
20	Breakwater	Labrax bergylta	1	7·5	*Podon intermedius,* young *Temora longicornis, Temora* nauplii.
		Lepadogaster Candollei	1	4	Young *Temora longicornis.*
		Scomber scomber	6	3·5–8·5	*Temora* nauplii, Copepod remains.
		Nerophis lumbriciformis	1	10·5	Young Copepods, Copepod nauplii.
		Rhamphistoma belone	1	29	No food.
	Panther	Syngnathus rostellatus	1	105	Decapod larvæ remains.
		Rhombus lævis	1	14	Copepod remains.
		Gobius sp.	1	13	,, ,,
		Labrus bergylta	1	10	,, ,,
	Off White Patch	Scomber scomber	1	5·5	*Temora* nauplii, remains of young Copepods.
22	Breakwater	Rhombus maximus	1	14	*Balanus* nauplii, *Centropages typicus.*
		Syngnathus acus	1	31	No food.
		Gasterosteus spinachia	2	75–79	Amphipod and Harpacticid remains.
	Knap	Rhombus maximus	1	11·5	*Temora longicornis.*
		Nerophis lumbriciformis	1	10	No food.
		Gobius sp.	1	12	Young *Temora* and *Temora* nauplii.
30	Breakwater	Syngnathus rostellatus	1	45	Crab zoæa, *Acartia* sp. *Pseudocalanus elongatus,* other Crustacea remains.
	Knap	Onos mustela	1	2	No food.
Sept. 3	Off White Patch	Gobius minutus	1	2	No food.

Date. Sept.	Locality.	Fish.	No.	Size in mm.	Food present.
4	Inside Breakwater	Gobius minutus	2	14	*Temora longicornis, Pseudocalanus elongatus, Acartia* sp.
		Syngnathus rostellatus	1	105	Larval decapod remains.
	Breakwater	Gobius minutus	1	8	No food.
		Clupea sprattus	1	11	,,
		Ammodytes lanceolatus	1	11	Copepod remains.
	Knap	Caranx trachurus	1	30	*Calanus finmarchicus, Porcellana* larva, Crustacea remains.
6	Breakwater	Clupea sprattus	1	23	No food.
	Outside Breakwater	Labrus bergylta	1	11	*Pseudocalanus elongatus.*
10	Off White Patch	Gobius minutus	1	10	Copepod remains.
12	Panther	Gobius minutus	1	4·5	No food.
		Gasterosteus spinachia	1	85	,,
	Off White Patch	Gobius minutus	1	7	,,
17	West Channel	Trachinus vipera	1	22	Copepod and other Crustacea remains.
	Breakwater	Ammodytes lanceolatus	20	7–14	*Acartia* sp. other Copepod remains.
		Scomber scomber	3	7–16	*Temora longicornis* Copepod remains.
20	Inside Breakwater	Gobius minutus	1	3	No food.
21	Breakwater	Syngnathus acus	1	7·5	*Centropages typicus.*
		Ammodytes lanceolatus	3	9–12	*Acartia clausi Pseudocalanus elongatus,* Copepod remains.
	Knap	Trachinus vipera	1	22	*Pseudocalanus elongatus, Anomalocera Pattersoni.*
		Caranx trachurus	1	30	*Centropages typicus, Temora longicornis.*
26	Off White Patch	Blennius galerita	1	17	*Temora longicornis.*
28	Breakwater	Caranx trachurus	1	30	Copepod remains.
		Syngnathus acus	1	85	*Pseudocalanus elongatus, Temora longicornis, Acartia clausi, Corycæus anglicus, Centropages typicus.*
Oct. 3	Panther	Trachinus vipera	1	5	*Pseudocalanus elongatus, Temora* nauplius.
		Gadus luscus	1	4	*Pseudocalanus elongatus.*
	Breakwater	Ammodytes lanceolatus	3	8–9	Green food remains, *Oithona* sp. Copepod remains.
	Knap	Clupea sprattus	1	27	*Pseudocalanus elongatus.*
5	Knap	Ammodytes lanceolatus	1	10	Copepod remains.
15	Knap	Lepadogaster Gouani	1	6 ca.	*Centropages typicus, Pseudocalanus elongatus.*
	Panther	Syngnathus acus	1	60	*Temora longicornis, Centropages typicus, Pseudocalanus elongatus, Paracalanus parvus.*
		Nerophis lumbriciformis	1	40	No food.
17	West Channel	Clupea harengus	1	9	,,

Date. Oct.	Locality.	Fish.	No.	Size in mm.	Food present.
19	Knap	Gadus luscus	1	7	*Pseudocalanus elongatus, Acartia clausi, Calanus finmarchicus.*
	Panther	Callionymus lyra	1	2	No food.
22	Knap	Clupea sprattus	1	6	Green food remains.
	Breakwater	,,	1	5	*Tintinnopsis ventricosa.*
23	Cawsand	Caranx trachurus	1	40	*Idya furcata*, Harpacticids indet. *Temora longicornis*, crab zoæa.
26	Breakwater	Clupea harengus	1	8·5	No food.
Nov.					
1	Breakwater	Callionymus lyra	1	2	No food.
5	Off White Patch	Clupea harengus	4	11–18	,,
		Clupea sprattus	1	6	,,
		Syngnathus rostellatus	1	45	*Pseudocalanus elongatus*, Copepod remains, ova.
	Panther	Crystallogobius Nilssoni	1	21	No food.
6	West End of Breakwater	Clupea sprattus	1	5·5	,,
		Ammodytes tobianus	1	5	Copepod nauplii.
	Breakwater	,,	1	5	No food.
		Clupea harengus	2	8–13	,,
		Clupea sprattus	1	5	,,
19	Off White Patch	Ammodytes tobianus	1	4	,,
20	Off White Patch	Clupea sprattus	1	6	,,
	Panther	,,	1	5	*Thalassiothrix nitzschoides.*
		Clupea harengus	1	6	No food.
	Breakwater	Gadus luscus	1	4	,,
		Clupea sprattus	7	6–8·5	Green food remains, Copepod nauplii remains, *Pleurosigma* sp.
23	Off White Patch	Clupea harengus	6	6·5–9	No food.
	Panther	,,	1	6	,,
26	Panther	,,	1	9	,,
Dec.					
11	Off White Patch	,,	1	7	,,

A Preliminary Account of the Production of Annual Rings in the Scales of Plaice and Flounders.

By

D. Ward Cutler, M.A.
Assistant Lecturer in Zoology, University, Manchester.

With Figures 1–10 in the Text, and Tables I to VI at the end.

It is only within comparatively recent times that it has been proved that the otoliths and scales of certain Teleostean fish can be used for the determination of their age.

Rings of growth, as they are called, are produced on these structures, and it is by counting the number that the age is ascertained, in much the same way as the approximate age of a tree may be determined by counting the annual rings.

In May, 1915, I was appointed as a temporary assistant naturalist to the Marine Biological Association at Plymouth, and at the suggestion of Dr. Allen decided to devote my time to an investigation of the otoliths and scales of Flounders and Plaice. My work on the otoliths I hope to publish at a future date.

It has often been asserted that the scales of these fish are of little or no value as age determiners. Thus Cunningham in 1905 stated that though summer and winter lines of growth are visible, yet "in most cases the zones are somewhat difficult to distinguish, and it would be by no means easy to form a confident judgment of the age of the fish by examination of the scales alone. The conclusion drawn from the scales must be confirmed or tested by examination of the otolith."

This preliminary account of my work is divided into two parts: in the first I hope to show that it is possible to ascertain the age of Flounders and Plaice by an examination of their scales, just as accurately as by the otoliths, in fact that the otolith growth rings and those found on the scales give identical results.*

---

* The annual rings on the otoliths of Flounders are not so distinct as those of the Plaice, indeed Wallace and other workers on otoliths hold that age determination is uncertain from Flounder otoliths. The scales which I have examined from these fish exhibit maxima and minima as regularly and distinctly as do those of the Plaice.

The second part will deal with experiments which were performed with a view to solving the problem of what are the conditions necessary to the production of these annual rings.

PART I.

METHODS.

A very few observations were sufficient to convince me that it was impossible to detect with any certainty rings on the scales of either Flounders or Plaice by the ordinary methods of examination. The sclerites, that is the thickened cells covering the scale, were apparently of such a uniform width that it was almost impossible to differentiate between the wide ones formed in the summer and the narrow winter ones.

In 1915 Winge published a paper on the scales of the cod, and described a new method which he had employed for his investigation.

His method was as follows: " A microscope stand with mechanical stage and ocular micrometer, and an objective having a focal diameter of about 8 mm. form the best combination. . . . One or more scales—fresh scales are especially suitable on account of their transparency—are placed on the object glass, their longitudinal axis about parallel with the longitudinal direction of the object glass itself. The micrometer is turned so as to fall parallel with the scales. . . . In order to obtain a curve for one of the scales the instrument is focussed to the centre of the one selected, and all sclerites in the longest radius of the scales then measured. . . . In order to provide a survey of the values thus obtained, the units are noted down on square-ruled paper. A horizontal axis is drawn, from which the measurements of the calcareous plates are marked off in a perpendicular direction, one by one, against each perpendicular line on the paper. On joining up the points thus obtained by straight lines, a curve is produced, which gives a distinct view of the variations in the breadth of the sclerite rings from the centre of the scale towards its periphery. Where the curve is low, the sclerites have been small, where it lies high, they have been large. A glance at the horizontal axis will show how many sclerites in all the scale contains, as also the number situate between each minimum, and the next. The growth rings are thus shown graphically as an alternation of maxima and minima."

The method given above is broadly the one which I employed in my investigations. The scales were examined in fresh water. The proportional width of successive sclerites is obviously the important factor to determine, thus making the absolute width of each sclerite of little importance. I used the distance between two degrees marked on the micrometer as the unit, each division being 10 μ.

The values so obtained were then plotted on squared paper as described above, ten units of the paper in a vertical direction, representing one division of the micrometer ; thus fractions of a unit are easily plotted. By this method small differences in the widths of successive sclerites are easily detected, and by it I found that growth rings on Plaice and Flounder scales are as distinctly shown as in the scales of other fishes.

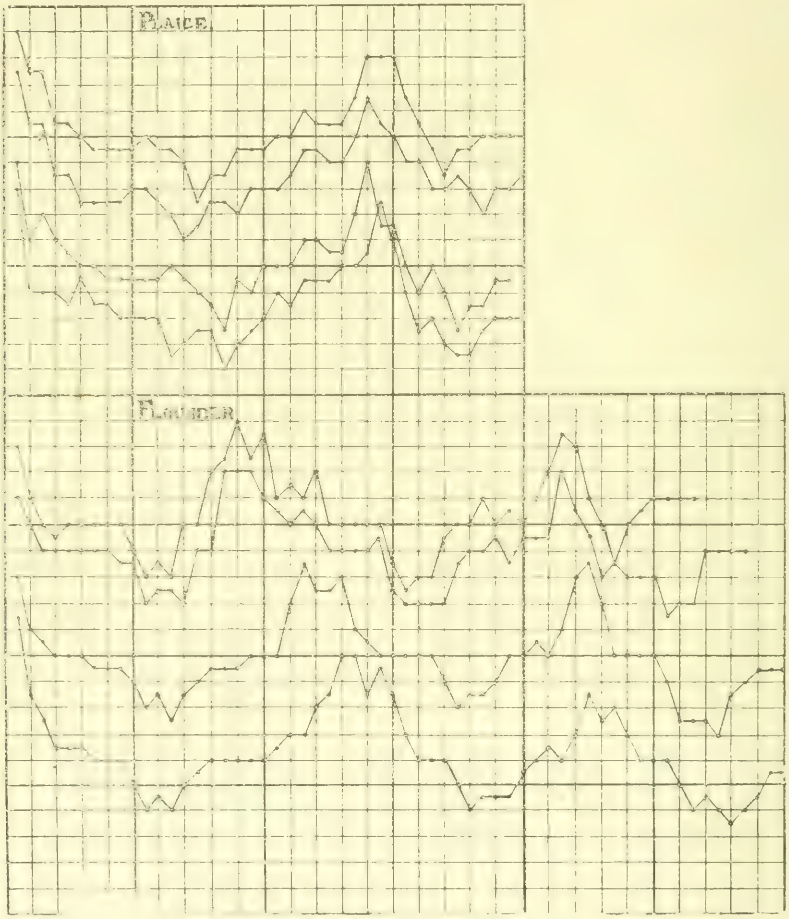


FIG. 1.—Scale curves from two fish, a Plaice and a Flounder. Four curves are drawn for each fish. Note the great resemblance between the four scale curves of each series.

SCALE INVESTIGATIONS.

The total number of fish examined was 137, of which 85 were Flounders and 52 Plaice. In order to determine if there were any marked

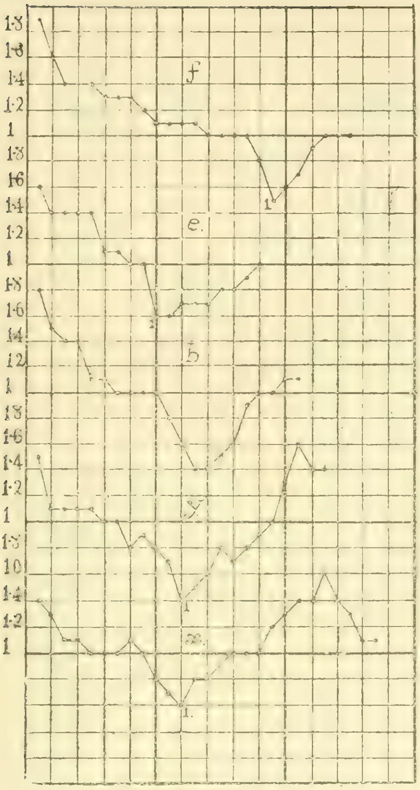


FIG. 2.—Scale curves of one year old fish. The letters refer to Table I.: the figures indicate the first winter's growth.

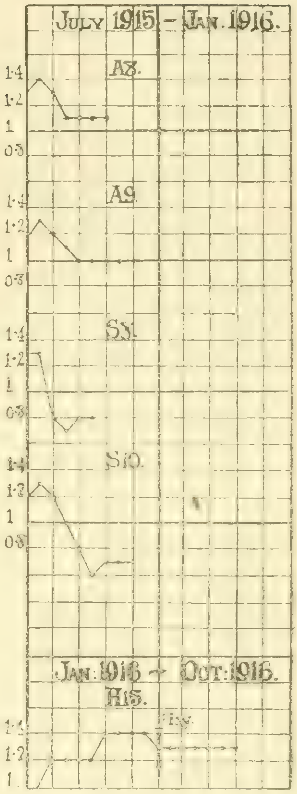


FIG. 10.—Partial curves of scales from fish in bad condition.
A = abundant tank.
S = scanty tank.
H = hot tank.
The numbers indicate the fish in the corresponding tables.

IN FIGURES 2 TO 10 THE DOTS ON THE CURVES REPRESENT THE WIDTHS OF THE SCLERITES OF THE SCALE. THESE ARBITRARY WIDTHS ARE GIVEN AT THE SIDE OF EACH CURVE.

IN FIGURES 5, 6, 7, 8, 9 THE FIRST DOT ON THE CURVES INDICATES THE WIDTH OF THE LAST SCLERITE ON THE SCALE BEFORE THE FISH WAS EXPERIMENTED UPON; THE SECOND DOT INDICATES THE WIDTH OF THE FIRST SCLERITE PRODUCED UNDER ARTIFICIAL CONDITIONS.

IN EACH FIGURE THE LINE DIVIDING A CURVE INTO TWO PARTS IS THE LINE OF DEMARCATION BETWEEN TWO PERIODS OF THE EXPERIMENT.

variation between scales taken from different parts of the body, four scales from various regions were examined in 45 cases. It will be seen by reference to Fig. 1 that, apart from minor variations, the scales from the same fish are very constant. The personal error was eliminated as far as possible by measuring these scales on different days, no reference being made to any previous measurements before the whole series had been completed.

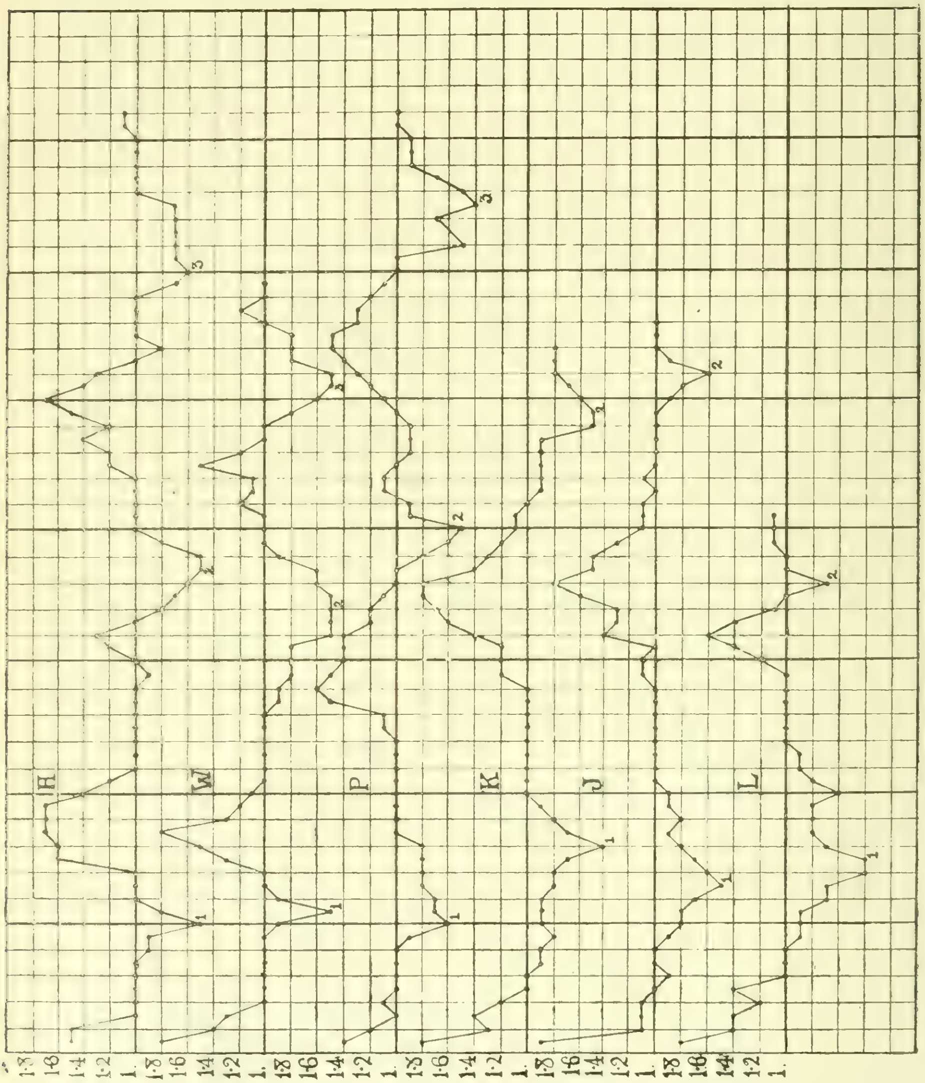


Fig. 3.—Scale curves from 2 and 3 year old fish. The letters indicate the same scales in Table I.; the numbers the successive winter zones.

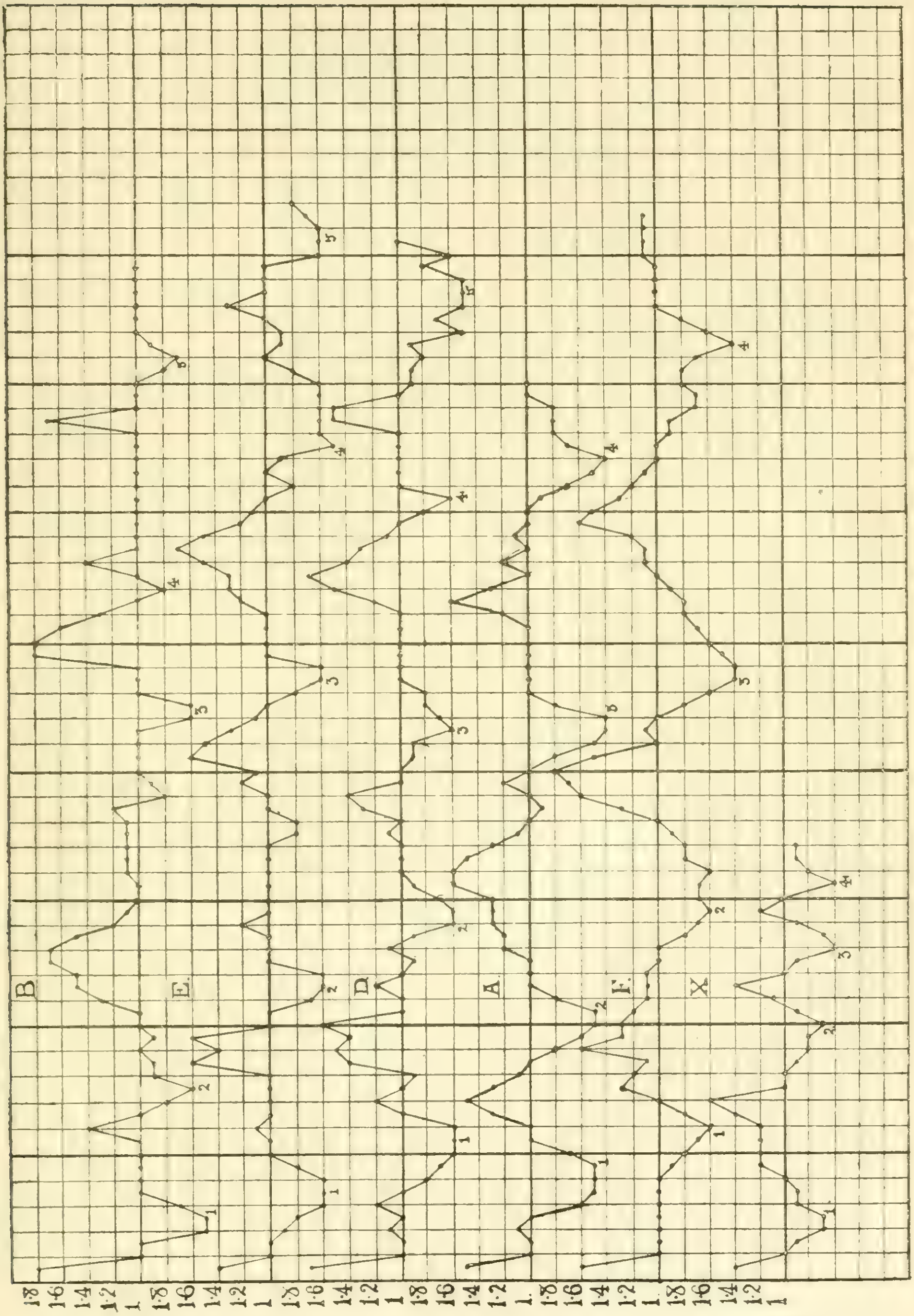


FIG. 4.—Curves from the sclerites of 4 and 5 year old fish. The letters refer to those given in Table I: the numbers indicate the successive winter zones of growth.

Miss Esdaile from her examination of salmon scales found that those taken from various regions of the body invariably show great changes in the number of the sclerites formed. This undoubtedly occurs in the Plaice and Flounder, but by no means to the same extent; when it is found there is a correlation between the number of sclerites and the size of the scale, the longest scale having the greatest number of sclerites. Winge found that in the cod there were considerable variations in the breadths of corresponding sclerites of different scales. I have not had the same experience in either Plaice or Flounder scales. It is obvious, therefore, that the growth of a big scale does not consist in making broad sclerites, but in increasing the number.

The scales from fishes of different ages have been examined, and in all cases I have found that the growth rings which they exhibit are identical with those which were seen on the otoliths. Scale curves exhibiting these rings are given in Figs. 2, 3 and 4. Fig. 2 shows curves from five first-year fish: six curves from two and three year old fish respectively are seen in Fig. 3: while Fig. 4 represents six curves from three four and three five year old fish respectively.

It will be noted that the periods of maximum and minimum breadth formation in the sclerites are very clearly shown.

It will also be seen that the first sclerite of the scale, that is the one nearest to the centre is always broad, the succeeding ones becoming narrower as the distance from the centre increases. This is of interest in connection with the view that I hold, that the width of the scale primarily depends on the temperature of the surrounding water. The young of the Plaice and Flounder are usually born about the end of April: scales are, however, not produced until a month or six weeks later, thus the scale growth is not begun until the temperature of the water is relatively high. At this period the temperature of the sea at Plymouth is usually between 13° and 13·5° C., as compared with about 9° C. in March. The same fact was noted by Winge for the cod scales which he examined from the Faroes.

Although the maxima and minima of the curves are quite sharply marked out, yet in many scales one notes minor depressions or elevations as in the scales D Fig. 4 or H Fig. 3. These secondary maxima and minima, as they have been called by Winge, are very common and are due, I think, to local variations of the conditions in which the animal was living. A short period of lowered temperature being sufficient to account for a secondary minimum: the converse conditions bringing about a secondary maximum.

In Table I. (p. 491) I have given the details of some of the fish which I have examined. The first column gives the age as determined by the otolith, the second the length as measured from the tip of the snout to the

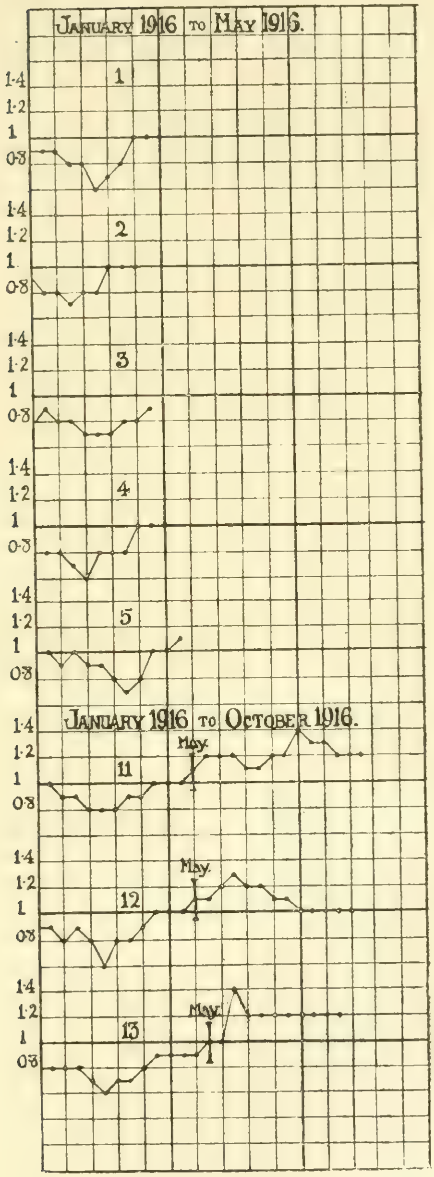


FIG. 5.—Partial curves of scales from control fish. The number over each scale curve indicates the corresponding scale in Table II.

end of the tail, and the third the number of annual rings which the scale exhibited. The figures in brackets are the number of sclerites produced towards the last and incomplete annual ring. In the fourth column is noted the number of sclerites formed during each year's growth.

The first point of interest arising from this table is the great variations in length that occur between fish of almost the same age; thus the length for second year fish varies from 7·9 to 9·6 cm., increasing as the fish enters on its third year of life, so that in one case a fish of 25·5 cm. in length was found to be but 2¾ years old. Again, I have enumerated fishes in their third year of life with lengths, 15·5 cm., 25 cm., 27·3 cm., and 32·1 cm. respectively.

It is true that in the normal conditions there would in all probability not be these enormous differences in the lengths of fish of the same age, because the external conditions would be more or less uniform for the fish of the same district. This condition has not been fulfilled, for a few of the animals in the Table, for experimental reasons, have been subjected to temperature variations and changes in the amount of food. In many cases, where the length is great in proportion to the age the animals have probably received more food than one would expect them to get from their normal habitat.

A further point to be observed is that the number of sclerites formed in the scale seems to be correlated with the condition and length of the fish; thus of the third year fish, marked †, the one 15·5 cm. long had but 28 sclerites, while of the others those with lengths 32 cm. and 32·1 cm. had 62, and 75 sclerites respectively. The three fish selected exhibit this phenomenon very clearly, but in practically all cases the same condition obtains. Thus I feel that I am right in stating that on the whole the sclerite formation and the growth in length are correlated.

J. Stuart Thomson, in his paper on the scales of the Gadidæ (p. 74), comes to the conclusion that intensive growth favours the production of a small number of sclerites.

To illustrate this he takes the case of a pollack three years of age and 27·62 cm. in length. Examination of the scales showed the following number of sclerites for each year: year I, 13; year II, 13; year III, 18. From this he goes on to say: "We have evidently here to deal with a rapidly grown fish, and this fact has expressed itself in the formation of the scale, in the small number of lines of growth for the first and second year. The more intensive the growth the smaller the number of the lines of growth. To compare with this we might take the case of a slower growing pollack, 44·40 cm. The scale of such a pollack shows the following lines: year I, 21; year II, 29; year III, 18; year IV, 2."

I do not quite understand this statement because, according to Thomson's Table, the first fish mentioned, of length 27·62, was small

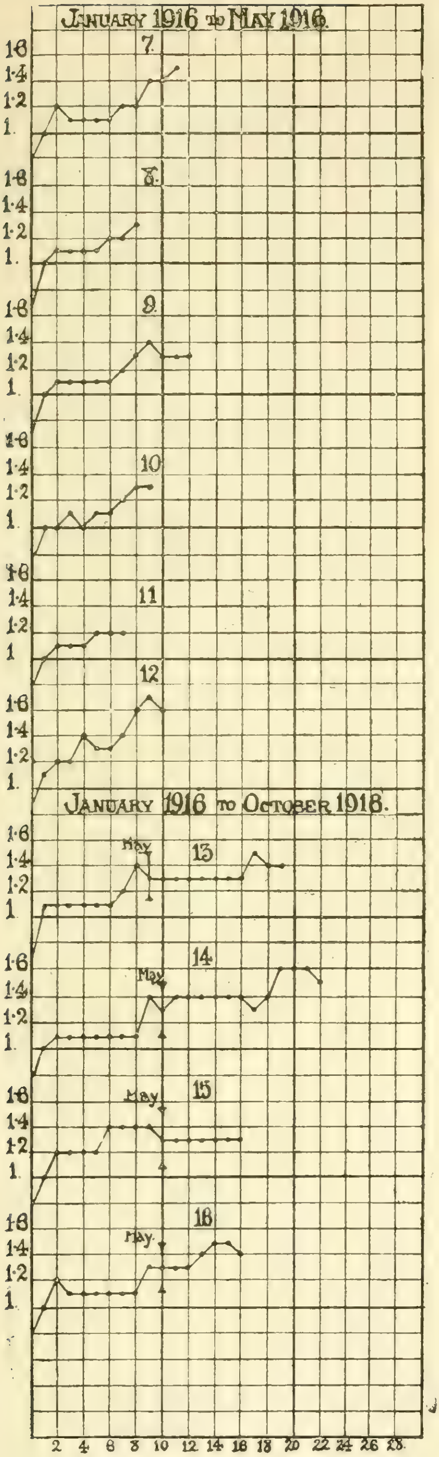


FIG. 6.—Partial curves of scales from fish living in hot water tank. In this and the following figure the vertical lines passing through some of the scales are the lines of demarcation between two periods of the experiment. The figure over each curve indicates the corresponding scale in Tables III. and IV.

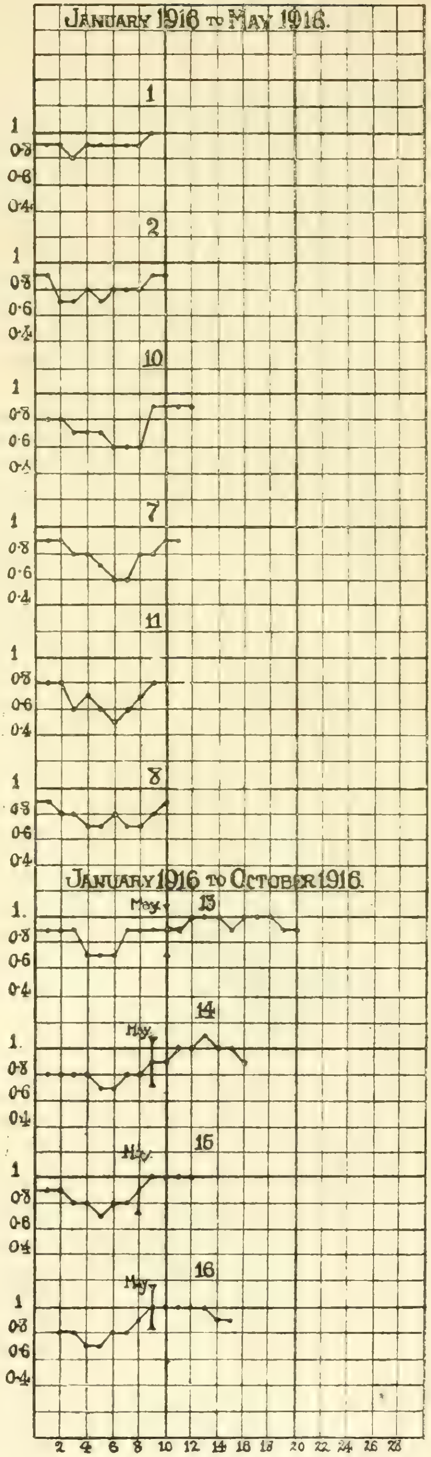


FIG. 7.—Partial curves of scales from fish living in cold water tank.

for its age, while the second one, of length 44·4 cm. was about normal, thus it seems to me as though the first fish instead of showing an intensive growth rather exhibited a slow one. If this is so the conclusion Thomson arrived at is practically reversed, and rather is in accordance with my results.

Cases are often seen where a fish is in good condition, but the total number of sclerites is somewhat small as is also the length ; such a one is the 4½ year old fish of length 27·8 cm., the scale curve of which is seen in Fig. 4 A. The condition when examined was excellent, and one would have thought the length would have been greater. The number of sclerites formed during each year of growth is, however, instructive ; during the first year there were nine, the second eleven, but during the two following years this number was increased to twenty-four for the third and twenty for the fourth year. I should interpret this as meaning that during the first two years of life the conditions for growth were unfavourable, but that they improved later on. This is borne out by the four-year-old fish, of length 26·8 cm., whose scale curve is seen in Fig. 4 X. The condition of the animal was poor when examined and the total number of sclerites very few, thirty-four. During the first year only four were produced, and but six and five for the third and fourth years respectively. The number sixteen for the second year seems to indicate a period of more favourable conditions.

A summary of the first part of my investigations is that the age of Plaice and probably Flounders can be accurately ascertained by the examination of the scales without reference to the otoliths. Having seen that two distinct breadths of sclerites are produced during each year, the problem arises as to what are the factors concerned in their production, and it is with the experiments which I performed in order to ascertain this, that the next part of the paper deals.

PART II.

Previous workers on fish scales have assumed that the annual rings are produced either by seasonal variations in the temperature of the water, or by fluctuations in the food supply. I therefore resolved to ascertain by experiment what part these two factors actually played in scale growth.

METHODS.

Four tanks at the Plymouth Laboratory were placed at my disposal and into each of these from 12–16 fish were placed ; both Plaice and Flounders being used.

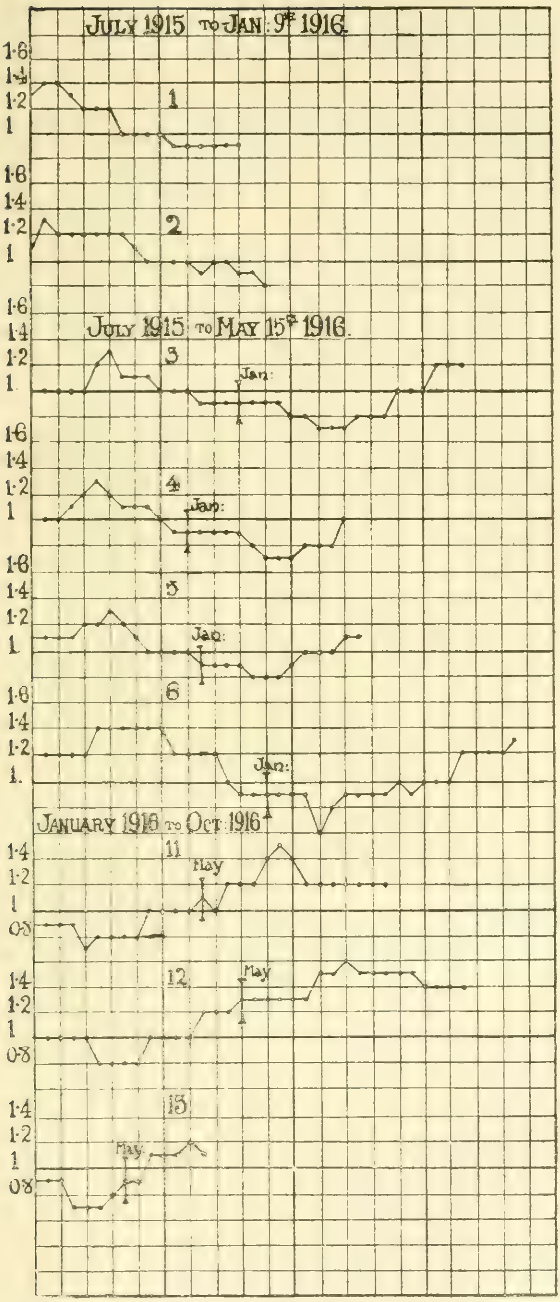


FIG. 8.—Partial curves of scales taken from fish which had been fed abundantly. The number over each curve indicates the corresponding scale in Table V.

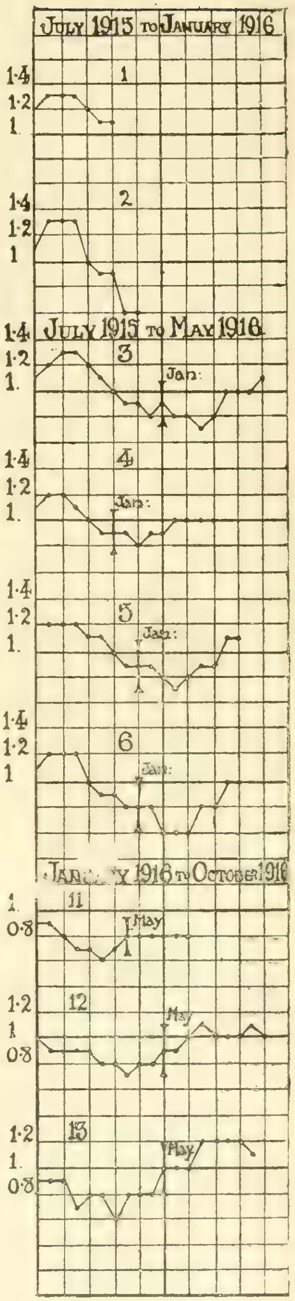


FIG. 9.—Partial curves of scales taken from fish which had been scantily fed. The number over each curve indicates the corresponding scale in Table VI.

Before putting the fish into the tanks scales were taken from the regions just above the pectoral fin and examined and scale curves made from each specimen.

The length of each fish was recorded and the animal marked. This was done by tying pieces of various coloured silks round the tail.

The experiments started about the middle of July, 1915. On January 9th, 1916, each fish was re-examined and scales taken from the same region as before, the length also being recorded.

The fish were then allowed to remain undisturbed until the following May, when about half a dozen from each tank were killed by chloroform, and scales again taken. This method of procedure was necessary because of my having, during the course of the experiments, removed from Plymouth to Manchester and I was unable to go to Plymouth in order to remove the scales from the living animals. The remaining fish were kept under experimental condition until the beginning of October, 1916, when they were killed, measured, and scale samples sent to me.

The experimental conditions under which the animals lived were as follows: the temperature of the water in two of the four tanks was varied, one being kept at a temperature as high or higher than the normal summer temperature of the sea water in the tanks at Plymouth, while the temperature of the other was kept as low as possible.

The remaining two tanks were used for feeding experiments, the temperature being that of the sea water in circulation in the tanks at Plymouth.

HOT AND COLD TANKS.

The temperature in the hot tank was obtained by running in sea water that had previously been heated. During the first part of the experiment, that is from July to January, the results were not very satisfactory, because the heating apparatus was turned off during the night and the tank water allowed to cool. Although it never reached the normal temperature yet there was a difference of 3–4° C. between the night and day temperatures. After January, however, a new apparatus was kindly devised by Mr. Matthews which maintained the water at a constant temperature day and night.

The artificial cooling of the cold tank was done by running sea water through glass tubes, which were surrounded by ice. This apparatus was quite successful in cooling the water, but as the ice was not renewed during the night the temperature of the tank rose a little. The result of this was a slightly fluctuating temperature, which was, however, not sufficient to nullify the experiments, the fluctuations not being more than 3° C. in the summer, and between 1° and 2° for the winter and autumn.

I give below the average temperature for each month of the hot and cold tanks, together with that of the sea water in the tanks at Plymouth.

1915.

	July	August.	September.	October.	November.	December.
Normal.	15·5°	17·3	15·8	14·6	11·3	10·9
Hot.	18·6	19·7	19·5	19·8	15·9	17
Cold.	13·9	13·7	14·1	13·3	10·9	10·3

1916.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.
Normal.	11·8	10·8	9·7	11·2	13	13·2	15	17·5	16	14·6
Hot.	16·9	17·2	17·7	17·9	17·9	17·9	18	19·6	19·5	16·6
Cold.	10·3	9·5	8·6	9·8	11·6	12·4	13·6	13·7	14	13·6

It will be seen that as regards the hot tank the temperature throughout was practically as high or higher than the highest temperature recorded for the normal sea water. Also the temperature was fairly constant from month to month.

As I have already indicated the cold tank records are not as satisfactory : in every month the temperature was below that of the normal, but in some cases it was above the winter temperature of the normal sea water. It was, however, in all cases far below the corresponding one for the hot tank.

"ABUNDANT" AND "SCANTY" TANKS.

These two tanks were the ones in which feeding experiments were conducted and the temperature was undisturbed. In the abundant tank the fish were fed excessively, that is to say, twice a day they were given as much food as they would take. The food was varied, sometimes squid, at other times worms, etc.

The fish in the scanty tanks were by no means so well treated : they were given very little at a time and never more than once a day : it was common to feed every other day.

In January control fish were started whose scale growth was investigated in exactly the same way as the others.

These fish were kept in an aquarium tank together with other species and were treated in exactly the same way, being fed once a day neither abundantly nor scantily.

RESULTS OF THE EXPERIMENTS.

In Tables II, III, IV, V, VI (p. 494), I have given the details of the fish experimented upon : the ages as computed from both otolith and scale are found in column two ; and it is worth noting here, that the age was first determined from the scales and then confirmed by the otolith at the end of the experiments. In no case was there any discrepancy between the two results.

In the next column are given the details of the scale growth for the periods between the examinations. First there is the number of sclerites formed during each period, followed by the maximum and minimum breadth of the sclerites. Finally I have given the increase in length of the animals during the periods and their general condition.

Figures of partial scale curves are reproduced, the portion figured being that part of the scale produced during successive periods of experimental conditions. The micrometer unit employed was the same as that for the curves in Part I.

CONTROL FISH.

The control tank, Table II, shows how uniform was the growth of both scale and fish during the two periods of the experiment. With the exception of those fish whose condition was not very good the increase in length from January to May is remarkably constant, as is also the number of sclerites formed. Also the maximum breadth is between 0·9 and 1·1 and the minimum between 0·8 and 0·6. Fig. 5, which represents the scale curves of some of these fish, is interesting in showing how closely the curve follows the temperature changes. They all start with a relative breadth for the sclerites of 0·9 or 0·8, which falls to a minimum in about the middle of the curve, then gradually rises to either 0·9 or 1·1 When we remember that the temperature in January was 11·8° C. falling to 9·7° C, in March and gradually rising to 13° C, by May, these curves seem very significant.

The growth during the period from May, 1916, to October, 1916, is equally interesting. The increase in length is a little greater than during the previous portion of the experiment, as would be expected. As regards the sclerites we note that the maxima and minima are greater in accordance with the higher temperature during these months. The scale curves also follow very closely expectation, if we assume that temperature is the directive agent in the production of wide or narrow sclerites.

In the curves of scales figured for the period, January to October, I have drawn a line through the portion where the growth up to May ended. This procedure I have followed in all the scale curves reproduced in the figures.

HOT AND COLD TANKS.

At the commencement of the experiment great trouble was encountered in keeping the animals in the hot tank in good condition, and several times the experiment had to be restarted owing to the fish either dying or getting into extremely poor condition. This was possibly due to the daily rise and fall of the temperature caused by the imperfect apparatus employed, because, after January, when the new apparatus had been installed this difficulty was not encountered, the fish in most cases appearing in quite normal condition. On account of this the results of the experiments between July, 1915, and January, 1916, have not received much attention, and although scale curves were made from each fish they have not been reproduced. This is not because they at all contradict the results of subsequent experiment, but because in most cases the fish had not lived long enough to exhibit much scale growth.

Of the six fish which did survive through the whole period, only three were at all in good condition, the others being much emaciated (see Table III).

From January to May the increase in length was in most cases a little greater than in the control tank, though the number of sclerites produced was practically the same. What is of great interest and importance, however, is the difference in the maximum and minimum breadths as compared with the controls. In no case was the maximum below 1·2 and the smallest minimum was 1. Further, the difference in breadth between the maxima and minima is small, in only two cases exceeding 0·4. This is of course as it should be, as the difference in temperature during the period was never greater than 1° C.

The scale curves, Fig. 6 (p. 479), are interesting in showing great similarity ; there is for all a sudden rise from below the 1 unit standard to a breadth of from 1 to 1·2. This width is maintained for a number of sclerites until a second rise is observed near the end of the period. These two rises, I think, synchronise with the increased temperature : first from 11·8° C., the normal for January, to 16·9° C. ; and secondly, between the end of March and beginning of April when the temperature was raised 1° C.

A further point which must not be overlooked is that at this period of the year, fish living in untreated water would be forming narrow sclerites, and their scale curve would be one showing a minimum, not a maximum. This I have shown to be the case with the control fish ; a comparison of their scale curves with those of Fig. 6, exhibits this in a striking way.

Of those fish that remained alive until October, the width of the sclerite formed at the end of the May period is maintained constant until a still greater width is attained at the margin of the scale. This, I believe, was due to the water in the tank rising from 17·9° to 19·7° between July and August.

The part of the table dealing with this period of experiment for the hot tank is almost a repetition of that for January to May.

I should like to call attention at this point to the two scales No. 12 and No. 15. The first of these shows an abnormally high width, while the second, though normal as regards the width of its sclerites, is remarkably deficient in them.

The fish to which scale No. 12 belonged was in very good condition and young : this was not the case with the fish from which No. 15 was taken. I attribute these peculiarities to nutriment, but will deal especially with this aspect of the problem in a later part of the paper.

The growth of the fish in the cold tank was, on the whole, very good. Table IV, which deals with the details of the fishes experimented upon, seems to show that the increase in length was slightly greater than that of the animals in the hot tank. There are, however, possibilities of error, such as faulty measurements and the small number of fish experimented upon, which make it impossible to draw any definite conclusions.

The figures of the maxima and minima for the sclerites for each period are, however, striking when compared with those of the corresponding periods for the hot tank animals. The figures are also lower than those for the control tank, though the difference is not very marked. This is, however, to be expected when it is remembered that it was only possible to keep the temperature of the cold tank a few degrees below the normal.

The scale curves, Fig. 7 (p. 479), are very interesting in showing the marked difference between them and those of the hot tank for the period of January to May. In all cases, and this was found in scales not figured, the curve never rises above unity, while in the hot tank it never falls below that width.

For the period January to October, the curves have a tendency to rise : there is an increased width of sclerites for the months July to September, but the greatest width does not approach that of the hot tank fish for the same months.

Compared with the control scale curves, there is similarity, but we find that the widths are more uniformly low.

When considered in relation to the temperature for each month the curves follow very closely the varying changes in the degree of heat, which the water possessed in which the animals lived.

As in the case of the hot tank scale curves we note that these curves also follow one another very closely, only differing in minor degrees.

The results of the experiments on the scales of fishes living in artificially heated and cooled water seems to indicate clearly that the temperature of the water has a very marked effect on the width of the sclerites produced. It is well to remember in connexion with this that the feeding of the fish in the two tanks was exactly the same.

ABUNDANT AND SCANTY TANKS.

As I have already said in these two tanks the temperature of the water was not altered. The only difference in the way the fish were treated was as regards the amount of food given to them. As the experiment in the case of these two classes of animals progressed satisfactorily from the very beginning, that is from July, 1915, until October, 1916, I have included scale curves in the figures for the period, July, 1915, to January, 1916.

As regards the sclerites the Tables V and VI shows a uniformity among the fishes of the abundant tank which were in good condition ; of those in a bad condition at the end of the experiment I shall treat later.

Figs. 8 and 9 (p. 481) are scale curves of abundant and scanty fed fish respectively. They are very alike in their general aspect as regards the type of curve, and in each set the maxima and minima are produced at approximately the same time and in accordance with the rise or fall of temperature at that time. Further it will be noted that there is correspondence between the course of these curves and those of the control fish scales of the same period.

If food were the predominating cause of the winter and summer rings of the scales, the expectation would be that the scales from the two sets of fish would have been remarkably different : this, however, we see is not the case.

The increase in length of the fish, as shown in the table, is very different, the scantily fed animals not increasing to any great extent. Also the number of sclerites produced by the abundantly fed fish is in excess of those produced by the animals in any of the other tanks.

Figs. 8 and 9 show very clearly the great difference between the number of sclerites produced for a given period by fish in the two tanks.

The last scale figured, No. 13 of Fig. 8, is interesting in this connexion : the condition of the animal was never very good, and at the end of the experiment the increase in length was only 1 cm. ; that is, for a period of nine months this animal had only added 1 cm. to its length. In accordance with this we note that but 13 new sclerites had been added to the scale ; thus though the animal had been given the opportunity for feeding well it had for some reason not availed itself of it, and had thus become comparable with the fish of the scanty tank.

The converse of this occurred once or twice with the scantily fed fish, in that some of the more vigorous animals managed to obtain more than their share of the food given to them ; with the result that they increased in length much more than did their fellows and developed many more sclerites. Most examples of this have been omitted from the table, but scale No. 14 for the period of May to October exhibits the condition to a small extent.

In Fig. 10 (p. 473) are seen a few curves of the scales of fish from various tanks which were in bad condition. The first two curves are from two fish from the abundant tank, No. 8 and 9 in the table. In February, 1916, they both died in an apparently exhausted condition. The same applies to the scales S. 8, S. 10, being from fishes 8 and 10 of the scanty tank. It will be seen that the curves show the salient features of all those for that period taken from fish living in unheated water. They are characteristic, however, in showing the possession of very few sclerites, and in having the width of the sclerites slightly less than is usual.

Scale curve H. 15 is the most interesting in showing the predominance of temperature over nutrition in regard to sclerite form. It is a curve of a scale from a fish living in the hot tank, No. 15. From January to May the animal was in fairly good condition and produced 10 broad sclerites : from May to October, however, its condition was bad, but in spite of this six sclerites were produced and instead of being narrow, as might have been expected if food were the cause of width variation, they retained the broad width of 1·3.

In all cases the same effect is seen, that the lower nutrition, leading to a poor condition, results in the lessening of the number of sclerites produced, but does not affect the breadth.

Reference to the tables will show that where the condition of a fish is reported as poor, very thin, etc., the number of sclerites produced is small, but the maximum and minimum widths remain similar to those for fish in good condition.

CONCLUSIONS.

The conclusions which I draw from the result of these experiments on the scale growth of fish is, that the broad summer bands, which are caused by the sclerites formed during that period being wide, and the narrow winter bands, produced by narrow sclerites, are due to changes in the temperature of the water in which the animals are living. High temperatures, such as are found in the summer months, lead to the formation of broad sclerites, while the narrow ones are called forth by low winter temperatures.

Owing to the temperature of the water varying from month to month, or even from week to week, the scale curves do not show a continuous rise and fall, but exhibit at certain places secondary elevations or depressions, which I have termed secondary maxima and minima. These, I believe, to be due entirely to the above-mentioned variations in the monthly temperatures.

The amount of food which the fish consumes and its general condition does not affect the production of summer and winter bands : the only effect which poor nutrition seems to have on the scales is a tendency for the production of few sclerites. High food consumption leads to a high sclerite formation.

Thus the number of sclerites formed seems to follow hand in hand with the general metabolism of the animal.

Little experimental work on the cause of the appearance of winter and summer rings has been done. Winge came to the conclusion that external conditions were the causative agents, because of the identical appearance of the scales of cod captured off the Faroes.

On August 11th, 1911, six cod were captured and samples of scales taken. They were then liberated and were recaptured simultaneously nine months later. Of these, three fish of approximately the same size were selected, and from each fish five scales were taken, measured and a curve made. It was found that all the scale curves thus drawn were exceedingly alike, so much so as to include peculiar deviations in the course of the curves. Winge argues from this that external conditions were responsible for the form of the curves, because the fish must have lived together for the nine months before recapture, and must therefore have been subjected to similar external conditions, such as temperature and salinity. The supply of nourishment in the water must also have been the same for the three animals.

This experiment certainly indicates that it is the environment which controls the course of scale growth, but it does not show what particular factor is the principal agent.

J. Stuart Thomson in his paper on the scales of Gadidæ (p. 100) states that in his opinion it is the amount of food supply, rather than variation in temperature, which brings about the formation of annual rings in scales. His reasons for coming to this conclusion are two: The first rests upon the evidence afforded by a whiting which was kept in captivity in a tank at Plymouth from May, 1902, until July, 1903. The water in the tank was not treated in any way, and the animal was fed daily. When in July, 1903, the scales were examined the sclerites appeared of the same width, and no winter or summer rings were detected. The sclerites also seemed to be narrower than is the case with fish captured from the sea.

This result is in direct opposition to that which I have obtained, for my fish in the two tanks when the water was not artificially cooled or heated all showed distinct rings.

Also if food were the determining factor one would have expected that a fish fed daily, and which increased in length from 10–20 mm. to 21·5 cm. in fourteen months as Thomson records, would have exhibited broader, or at any rate as broad, sclerites as fish of the same age captured from the sea. Yet this is not so, the sclerites were narrower.

Again the total number of sclerites produced was about 50, but whiting from the sea of the same age showed about 43. This indicates that the animal experimented upon was in good condition and corresponded to my fish which were abundantly fed.

The second piece of evidence (p. 57) that Thomson adduces for his opinion is that deep-sea fishes are not exposed to seasonal variations of temperature and should not, therefore, show annual rings on their scales. In order to determine if this were so he examined scales from a haddock captured from 8–14 fathoms depth of water, and compared them with others taken from a haddock from 60–80 fathoms. The annual rings were as clearly marked in the latter as in the former.

It should be pointed out that 60–80 fathoms is not really deep water, and that seasonal variation does not disappear until a depth of 100 fathoms is reached. Indeed according to some oceanographers the variation would seem to extend to a slight extent to much greater depths.

In conclusion I wish to express a great gratitude to Dr. Allen for the interest he has taken in my work and for the many suggestions he has made to me: also for the facilities he has given me to enable the experimental part of the work to be carried out. I must also express my thanks to Mr. D. J. Matthews for suggestions regarding the apparatus used for the heating and cooling of the water in the tanks. My thanks are also due to Mr. A. J. Smith for the feeding and care of the fish during the period when I was away from Plymouth.

REFERENCES.

Cunningham, J. T. Zones of Growth in the Skeletal Structures of Gadidæ, and Pleuronectidæ. Annual Report of the Fishery Board of Scotland. 1905.

Esdaile, P. C. Intensive Study of the Scales of Three Specimens of Salmo salar. Memoirs and Proceedings of the Manchester Lit. and Phil. Soc. 1911–12.

Esdaile, P. C. The Scientific Results of the Salmon Scale Research at Manchester University. Memoirs and Proceedings of the Manchester Lit. and Phil. Soc. 1912–13.

Thomson, J. Stuart. Periodic Growth of Scales in Gadidæ as an Index of Age. Journ. Marine Biol. Assoc. 1904.

Winge, O. On the Value of the Rings in the Scales of the Cod as a Means of Age determination. Meddelelser fra Kommissionen for Havundersogelser. 1915.

TABLE I

Age by otolith.	Length in cm.	No. of annular rings.	Average number of sclerites in successive years.						Species.	Condition of fish.	Date scale was taken from fish.	
			I.	II.	III.	IV.	V.	VI.				
f1	2·6	1(+6)	19		—	—	—	—	not determined	very good	June 12, 1915	*captured
e1	2·7	1(+8)	10	—	—	—	—	—	,,	,,	,,	,,
b1	3	1(+8)	13	—	—	—	—	—	,,	,,	,,	,,
y1½	3·9	1(+11)	12	—	—	—	—	—	,,	,,	,,	,,
x1¾	7·1	1(+15)	12	—	—	—	—	—	Plaice	good	July 28, 1915	,,
2	7·9	2	12	20	—	—	—	—	Flounder	very good	,,	,,
2	7·9	2	10	26	—	—	—	—	,,	,,	,,	,,
K2	8·2	2(+6)	16	32	—	—	—	—	,,	,,	May 28, 1915	,,
J2	8·9	2(+4)	13	39	—	—	—	—	Plaice	,,	,,	,,
L2	9·1	2(+5)	14	22	—	—	—	—	,,	good	,,	,,
2	9·1	2(+3)	12	30			—	—	Flounder	very good	,,	,,
2	9·6	2(+7)	11	36	—	—	—	—	,,	,,	,,	,,
2¾	14·9	2(+16)	11	14	—	—	—	—	,,	good	,,	,,
2¾	17·5	2(+18)	14	19	—	—	—	—	Plaice	very good	June 12, 1915	,,
2¾	17·6	2(+11)	8	18	—	—	—	—	,,	,,	May, 1916	*H. Jan.–May, 1916
2½	19	2(+2)	15	17	—	—	—	—	Flounder	,,	Sept., 1915	captured
2½	20·2	2(+21)	14	32	—	—	—	—	Plaice	excellent	May 28, 1915	,,
2¾	25·5	2(+26)	16	16	—	—	—	—	Flounder	,,	May 12, 1916	A. July, 1915–May, 1916
†3	15·5	3	6	10	12	—	—	—	Plaice	fair	Aug., 1915	captured
3	20	3(+2)	10	12	6	—	—	—	Flounder	,,	May 28, 1915	,,
3¾	21·3	3(+12)	8	10	18	—	—	—	Plaice	good	Jan. 9, 1916	C. July, 1915–Jan., 1916

TABLE I—*continued.*

Age by otolith.	Length in cm.	No. of annular rings.	Average number of sclerites in successive years. I.	II.	III.	IV.	V.	VI.	Species.	Condition of fish.	Date scale was taken from fish.	
3	21·5	3	8	20	19	—	—	—	Flounder	good	Aug., 1915	captured
H3¼	22·6	3(+12)	10	27	23	—	—	—	Plaice	,,	May 28, 1915	,,
3	25	3(+12)	11	24	19	—	—	—	,,	,,	Jan., 1916	C. July, 1915–Jan., 1916
3½	25·2	3(+6)	14	24	20	—	—	—	,,	,,	Aug., 1915	,,
3	27·3	3	16	22	25	—	—	—	Flounder	,,	Jan., 1916	,,
3½	27·6	3(+6)	11	16	22	—	—	—	Plaice	,,	May, 1915	,,
3	28·3	3(+15)	6	32	26	—	—	—	Flounder	,,	,,	,,
3¼	28·4	3(+18)	9	24	31	—	—	—	,,	excellent	Sept., 1915	,,
3¾	28·6	3(+20)	7	17	12	—	—	—	Plaice	,,	Jan. 9, 1916	A. July, 1915–Jan., 1916
3	29·6	3	9	21	28	—	—	—	Flounder	,,	Aug., 1915	,,
3	29·6	3(+1)	7	28	25	—	—	—	,,	,,	June, 1915	,,
3¾	30·6	3(+10)	15	24	32	—	—	—	Plaice	,,	May, 1916	A. July, 1915–May, 1916
W3¾	30·5	3(+8)	11	23	17	—	—	—	Flounder	good	June 12, 1915	captured
3½	30·2	3(+6)	11	22	16	—	—	—	,,	,,	July, 1915	,,
3½	31	3(+8)	14	14	20	—	—	—	,,	fair	May, 1915	,,
P3	32	3(+7)	10	30	25	—	—	—	Plaice	excellent	June 12, 1915	,,
†3	32·1	3	16	26	20	—	—	—	,,	,,	May, 1915	A. July, 1915–May, 1916
†3	32·1	3	21	26	28				,,	,,	June, 1915	captured
4½	24·7	4(+3)	6	16	6	10			,,	poor	May, 1915	,,
4¼	25·5	4(+2)	8	8	27	24	—	—	Flounder	fair	Aug., 1915	,,
4	26·7	4(+2)	8	22	14	14	—	—	,,	,,	,,	,,
4	27	4(+2)	12	17	12	18	—	—	Plaice	,,	Sept., 1915	S. July, 1915–Sept., 1915

4½	27·8	4(+6)	9	11	24	20	—	—	Plaice	excellent	Jan., 1916	captured
4¾	28	4(+8)	8	10	15	16	—	—	Flounder	good	Sept., 1915	,,
4½	28·5	4(+5)	6	14	7	15	—	—	,,	,,	May, 1915	,,
4½	29·4	4(+15)	8	20	20	19	—	—	,,	very good	Aug., 1915	,,
4¼	29·5	4	12	30	16	24	—	—	,,	excellent	Sept., 1915	,,
4¼	30	4(+5)	10	12	16	18	—	—	,,	good	June, 1915	,,
4	30	4	13	10	13	31	—	—	,,	very good	Sept., 1915	H. July–Sept., 1915
4½	30·5	4(+6)	19	10	9	34	—	—	Plaice	,,	June, 1915	captured
4	30·6	4(+4)	18	12	12	17	—	—	Flounder	good	May, 1915	,,
4	30·6	4(+6)	14	10	15	8	—	—	Plaice	,,	Jan., 1916	A. July, 1915–Jan., 1916
4	30·6	4(+5)	18	18	22	22	—	—	,,	,,	Aug., 1915	captured
4	33	4(+7)	4	23	18	14	—	—	Flounder	very good	Jan., 1916	S. July, 1915–Jan., 1916
4¾	33·5	4(+10)	8	24	30	14	—	—	Plaice	good	Sept., 1915	C. July, 1915–Sept.,1915
F4	35·6	4(+10)	12	17	18	25	—	—	,,	excellent	May 28, 1915	captured
X4	26·8	4(+3)	4	16	6	5	—	—	,,	poor	Jan. 9, 1916	,,
5¼	30·5	5(+3)	10	8	10	12	15	—	,,	fair	,,	,,
E5	31·2	5(+3)	8	15	24	18	16	—	Flounder	good	,,	,,
D5	32·5	5(+15)	12	17	14	18	17	—	Plaice	,,	May 28, 1915	,,
B5	35	5(+7)	5	10	30	9	18	—	,,	very good	,,	,,
6½	34·5	6	6	8	7	7	12	6	Flounder	fair	,,	,,

---

* In the last column the word captured means the animal was taken straight from the sea, and did not live under experimental conditions before the scales were examined. A denotes that the animal lived in abundant tank; S in the scanty; H in the hot, and C in the cold tank before the scales were examined.

TABLE II

CONTROL TANK

			January, 1916 May, 1916.						May, 1916 October, 1916.					
	Age in years.	Species.	No. of sclerites.	Max.*	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length.	Increase in length.	Condition.
1	3	Flounder	10	1	·6	25·4–25·6	0·2	very good	—	—	—	—	—	—
2	3	,,	8	1	·7	25–25·1	0·1	good	—	—	—	—	—	—
3	3¾	,,	9	·9	·7	28·9–29	0·1	,,	—	—	—	—	—	—
4	3½	,,	10	1	·6	29·6–29·7	0·1	,,	—	—	—	—	—	—
5	4½	Plaice	11	1·1	·7	30·6–30·7	0·1	,,	—	—	—	—	—	—
6	3¾	,,	4	1	·5	28·9–28·9	0	fair	—	—	—	—	—	—
7	4	,,	7	·9	·8	28·9–29	0·1	good	—	—	—	—	—	—
8	4	,,	5	1	·7	30·5–30·6	0·1	fair	—	—	—	—	—	—
9	3	,,	7	1·1	·7	25·2–25·3	0·1	good	—	—	—	—	—	—
10	2¾	Flounder	9	1	·8	23·9–24	0·1	,,	—	—	—	—	—	—
11	4	,,	12	1·1	·8	30·0–30·1	0·1	,,	13	1·4	1·1	30·1–31·1	1	excellent
12	4	,,	12	1·1	·6	29·8–30	0·2	,,	12	1·3	1	30–31	1	,,
13	3	,,	13	1	·6	26–26·1	0·1	,,	10	1·4	1	26·1–27	0·9	,,
14	3½	Plaice	12	1	·7	28–28·2	0·2	,,	14	1·5	1·1	28·2–29	0·8	,,
15	3	,,	10	1·1	·8	27·5–27·6	0·1	,,	9	1·5	1·1	27·6–27·8	0·2	fair
16	3	,,	11	1	·6	27·1–27·2	0·1	,,	12	1·4	1	27·2–28	0·8	good

* In the columns labelled Max. and Min. are given the maximum and minimum widths of the sclerites for the period.

TABLE III

HOT TANK

			July, 1915–January, 1916						January, 1916–May, 1916						May, 1916–October, 1916					
	Age in years.	Species.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.
1	3	Flounder	11	1·8	1·3	24·6–25·5	0·9	good	—	—	—	—	—	—	—	—	—	—	—	—
2	4	,,	18	1·6	1·1	30·6–32·1	1·5	very good	—	—	—	—	—	—	—	—	—	—	—	—
3	3½	Plaice	8	1·6	1·1	26·2–27	0·8	good	—	—	—	—	—	—	—	—	—	—	—	—
4	3	,,	4	1·4	1·2	27·5–27·2	–0·3	poor	—	—	—	—	—	—	—	—	—	—	—	—
5	3	Flounder	5	1·5	1·3	28–27·8	–0·2	,,	—	—	—	—	—	—	—	—	—	—	—	—
6	2¾	,,	8	1·4	1	24·6–24·6	0	fair	—	—	—	—	—	—	—	—	—	—	—	—
7	4	,,	—	—	—	—	—	—	11	1·5	1	28–28·3	0·3	good	—	—	—	—	—	—
8	4	Plaice	—	—	—	—	—	—	8	1·3	1	29·5–29·6	0·1	fair	—	—	—	—	—	—
9	3	Flounder	—	—	—	—	—	—	12	1·4	1	26·2–26·8	0·6	good	—	—	—	—	—	—
10	2¾	Plaice	—	—	—	—	—	—	9	1·3	1	15·5–15·7	0·2	fair	—	—	—	—	—	—
11	4	Flounder	—	—	—	—	—	—	7	1·2	1	32·5–33·5	1	good	—	—	—	—	—	—
12	2½	,,	—	—	—	—	—	—	10	1·7	1·1	17·6–18·4	0·8	very good	—	—	—	—	—	—
13	3	,,	—	—	—	—	—	—	9	1·4	1·1	25·9–26	0·1	fair	10	1·5	1·3	26–26·8	0·8	very good
14	3½	Plaice	—	—	—	—	—	—	10	1·4	1	29·9–32·5	2·6	very good	12	1·6	1·3	30·9–32·5	1·6	excellent
15	4	,,	—	—	—	—	—	—	10	1·4	1	30·5–30·9	0·4	fair	6	1·3	1·3	30·9–30·7	–0·2	poor
16	4	,,	—	—	—	—	—	—	10	1·3	1	30–30·5	0·5	good	6	1·5	1·3	30·5–30·8	0·3	good

TABLE IV

COLD TANK

			July, 1915–January, 1916						January, 1916–May, 1916						May, 1916–October, 1916					
	Age in years.	Species.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.
1	3	Plaice	9	1	·8	24·2–25	0·8	very good	9	1	·8	25–25·5	0·5	good	—	—	—	—	—	—
2	3	,,	4	1	·8	28·3–28·3	0	,,	10	·9	·7	28·3–28·5	0·2	,,	—	—	—	—	—	—
3	3	Flounder	5	1	·9	25·2–25·5	0·3	good	—	—	—	—	—	—	—	—	—	—	—	—
4	3½	,,	12	1	·8	26·8–28·5	1·7	excellent	—	—	—	—	—	—	—	—	—	—	—	—
5	2½	Plaice	7	1	·8	21·7–22·2	0·5	good	—	—	—	—	—	—	—	—	—	—	—	—
6	4	,,	8	1	·9	30·5–31	0·5	,,	—	—	—	—	—	—	—	—	—	—	—	—
7	3	Flounder	6	1	·8	26·9–27·4	0·5	fair	11	·9	·6	27·4–27·8	0·4	very good	—	—	—	—	—	—
8	4	,,	8	1	·7	30·8–31·5	0·7	good	10	·9	·7	31·5–31·8	0·3	good	—	—	—	—	—	—
9	3½	,,	12	1	·8	26·8–28·5	1·7	very good	6	·8	·5	28·5–29·5	1	,,	—	—	—	—	—	—
10	3	Plaice	—	—	—	—	—	—	12	·9	·6	28–28·5	0·5	,,	—	—	—	—	—	—
11	4	,,	—	—	—	—	—	—	9	·8	·5	33–33·1	0·1	fair	—	—	—	—	—	—
12	2¾	,,	—	—	—	—	—	—	6	·9	·5	20·5–20·9	0·4	good	—	—	—	—	—	—
13	2	Flounder	—	—	—	—	—	—	10	·9	·7	19–21·5	2·5	very good	10	1	·9	21·5–24	2·5	very good
14	3	,,	—	—	—	—	—	—	9	·9	·7	24·5–24·7	0·2	good	7	1·1	·9	24·7–26·2	1·5	,,
15	2¾	,,	—	—	—	—	—	—	8	·9	·7	20·5–20·9	0·4	fair	4	1	·9	20·9–21·2	0·3	poor
16	3	,,	—	—	—	—	—	—	9	1	·7	25–25·6	0·6	good	6		·9	25·6–26·3	0·7	good

TABLE V

ABUNDANT TANK

			July, 1915–January, 1916						January, 1916–May, 1916						May, 1916 October, 1916					
	Age in years.	Species.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.
1	2¾	Flounder	16	1·4	·9	25·5–29·1	3·6	very good	—	—	—	—	—	—	—	—	—	—	—	—
2	2	,,	18	1·3	·8	24·5–28·3	3·8	,,	—	—	—	—	—	—	—	—	—	—	—	—
3	3	Plaice	16	1·3	·9	25·5–29·1	3·6	,,	17	1·2	·7	29·1–29·9	·8	very good	—	—	—	—	—	—
4	3¾	,,	12	1·3	·9	27·9–29·9	2	,,	12	1	·7	29·9–30·6	·7	,,	—	—	—	—	—	—
5	3½	Flounder	13	1·3	·9	27·2–28·6	1·4	,,	12	1·1	·8	28·6–29	·4	,,	—	—	—	—	—	—
6	4	Plaice	18	1·4	·9	32·1–33·5	1·4	,,	19	1·3	·6	33·5–34	·5	excellent	—	—	—	—	—	—
7	2¾	Flounder	6	1·1	·9	24–24	0	very thin	11	1·5	·9	24–24·6	·6	fair	—	—	—	—	—	—
8	4	,,	6	1·4	1·1	31–30·9	–0·1	,,	—	—	—	—	—	—	—	—	—	—	—	—
9	3¼	,,	7	1·3	1	26–26	0	poor	—	—	—	—	—	—	—	—	—	—	—	—
10	4	,,	20	1·3	·8	32–33·1	1·1	excellent	12	1·1	·8	33·1–33·7	·6	excellent	—	—	—	—	—	—
11	2	Plaice	—	—	—	—	—	—	13	1·1	·7	15·2–16·2	1	very good	14	1·5	1	16·2–18	1·8	excellent
12	3½	Flounder	—	—	—	—	—	—	16	1·3	·8	26–27·3	1·3	,,	17	1·6	1·3	27·3–29	1·7	,,
13	2¾	Plaice	—	—	—	—	—	—	7	·9	·7	17·5–17·6	·1	fair	6	1·2	·9	17·6–18·5	0·9	very thin
14	4½	,,	—	—	—	—	—	—	6	1	·8	27–27	0	,,	15	1·3	1	27–29·1	2·1	very good
15	4	Flounder	—	—	—	—	—	—	18	1·1	·8	28·3–29·7	1·4	excellent	24	1·3	·9	29·7–33·2	3·5	excellent

TABLE VI

SCANTY TANK

			July, 1915–January, 1916						January, 1916–May, 1916						May, 1916–October, 1916					
	Age in years.	Species.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.	No. of sclerites.	Max.	Min.	Length in cm.	Increase in length.	Condition.
1	4¾	Flounder	6	1·3	1·1	31·5–31·5	0	very thin	—	—	—	—	—	—	—	—	—	—	—	—
2	3¾	,,	8	1·3	0·6	28·5–28·6	0·1	,,	—	—	—	—	—	—	—	—	—	—	—	—
3	2¾	,,	10	1·3	0·8	20·2–22·4	2·2	good	8	1·1	0·7	22·4–23	0·6	fair	—	—	—	—	—	—
4	4½	Plaice	6	1·2	0·9	33·5–34	0·5	fair	8	1	0·8	34–34·2	0·2	,,	—	—	—	—	—	—
5	3	,,	8	1·2	0·9	21·3–21·5	0·2	,,	8	1·1	0·7	21·5–21·8	0·3	,,	—	—	—	—	—	—
6	3¾	Flounder	8	1·2	0·8	26–26·6	0·6	,,	8	1	0·6	26·6–26·9	0·3	,,	—	—	—	—	—	—
7	4½	,,	10	1·4	0·9	30·5–31·3	0·8	good	—	—	—	—	—	—	—	—	—	—	—	—
8	2¾	,,	5	1·3	0·7	24·9–24·9	0	very thin	—	—	—	—	—	—	—	—	—	—	—	—
9	4	,,	4	1·2	0·5	30–29·9	–0·1	,,	—	—	—	—	—	—	—	—	—	—	—	—
10	2	,,	8	1·3	0·6	20·5–20·6	0·1	,,	—	—	—	—	—	—	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—	7	0·9	0·6	33·5–33·6	0·1	fair	5	0·8	0·8	33·6–34	0·4	very poor
12	—	—	—	—	—	—	—	—	10	0·9	0·7	24·6–25	0·4	good	8	1·1	0·9	25–25·5	0·5	fair
13	—	—	—	—	—	—	—	—	10	1	0·6	30·5–31	0·5	,,	7	1·2	1	32–32·9	0·9	good
14	—	—	—	—	—	—	—	—	9	0·9	0·7	13·5–13·7	0·2	,,	12	1·3	1	13·7–16	2·3	very good
15	—	—	—	—	—	—	—	—	8	1	0·8	21·3–21·5	0·2	fair	9	1·2	0·9	21·5–22·5	1·5	good

A List of the Maritime, Sub-Maritime and Coast-frequenting Coleoptera of South Devon and South Cornwall, with especial reference to the Plymouth District.

By

James H. Keys, F.E.S.

PREFATORY REMARKS.

It may perhaps be well to say that by maritime species are meant those Beetles whose habitats are covered by the sea for a considerable time during the flow and ebb of the tide. By sub-maritime species are meant the dwellers at high-tide mark or thereabouts, subjected to occasional wettings by the sea, and the species inhabiting brackish pools and wet places in salt-marshes. The coast species comprise individuals living under stones and rejectamenta, as a rule safe from the reach of high tide, and those peculiar to the roots, leaves and flowers of plants attached to the coast, as well as inhabitants of wooden piles on the shore and the denizens of the ooze of fresh-water trickles on the cliffs—excepting species equally obtainable inland.

The Maritime Beetles included in the list comprise eight species, and are preceded by a double dagger (‡) for the sake of distinction; the Sub-Maritime amount to fifty-four species and are preceded by a single dagger (†); the Coast Species number eighty-nine, and are preceded by an asterisk (*).

The Plymouth District has been regarded as including any locality which in a day conveniently admits of four or five hours' collecting, in addition to the journey thither and back. Roughly speaking this embraces the coast line from Slapton Ley on the east to the Seaton Valley (Downderry) on the west.

The writer is fully conscious of the fact that his work necessarily falls considerably short of being a complete catalogue of the species indigenous to the district, as much of the extensive coast line has never been examined by any collector, whilst his own work at the foreshores of the several estuaries and at the numerous tidal creeks has been limited to a few localities of easy access. A large proportion of the country still awaits the attention of the Coleopterist. That it would repay careful research there need be little doubt, as the writer has seldom ventured into a locality previously unknown to him without having been rewarded by the capture of one or more species new to the district.

The obscure and unobtrusive habits of Beetles must in this connection be remembered. These characteristics, taken in conjunction with the fact that many species abundant in a favourable season may not be discoverable at all in the following year, render it desirable that likely places should receive frequent visits at suitable intervals, if the local Coleopterous Fauna is to be completely enumerated.

The absolute failure of the compiler to secure in the Plymouth area even a single exponent of the genus *Bledius*—and consequently of the genus *Dyschirius* which preys upon it—the ubiquitous *D. globosus* excepted—has long been a source of regret to him, and he cannot but think that they will yet be found in one or other of the creeks in the district, and particularly so as more than one member of both the genera have been taken in numbers at Dawlish Warren on the one side, and at several places in Cornwall on the other side of Plymouth.

Of the truly Maritime and Sub-Maritime Coleoptera there is little doubt as to the species which should be included in such a list as the present; but with respect to coast species the matter is not so readily determined. The main cause of doubt lies in the fact that the life-histories of so many beetles are not yet understood, and experience seems to show that species peculiar to the coast in one district are equally at home inland in another. A hard and fast line of demarcation in the matter of habitat is therefore not yet possible. But inasmuch as it is desirable to have authority in support of one's ruling, the writer, in the main, has adopted Fowler's Coleoptera of the British Isles as the guide for the inclusion of the coast species. A little discretionary power has been reserved however, and a few interesting species which occur with us only on the coast have been inserted in the list, although not definitely asserted by Fowler to be of that habit.

One must not omit to record the successful work of Commander J. J. Walker, R.N., at Whitsand Bay in the seventies and early nineties. With him rests the honour of having first discovered there such rarities as *Harpalus tenebrosus* and *Psammobius porcicollis*, as well as a long list of other uncommon Coleoptera, and the writer heartily acknowledges his obligation to Commander Walker for kindly having shown him the habitats of those species. In later years Mr. Philip de la Garde, R.N., did splendid work in the South Devon District, and several additions were made to the British List by him; but perhaps his most notable contribution to the local fauna was the capture at Dawlish of the much-desired *Arena octavii*. It will be long ere the lamentable breach caused by his untimely death can possibly, if ever, be filled.

In conclusion the writer wishes to acknowledge his indebtedness for the assistance he has received in compiling this catalogue to an incompleted manuscript list of the Devonshire Coleoptera, the work of his late lamented friend, Mr. Philip de la Garde, R.N., and he also has to thank his friend, Mr. E. A. Newbery, for valued suggestions and help.

October, 1917.

GEODEPHAGA.

*CICINDELA GERMANICA L. Seaton, June, 1895, de la Garde.

†DYSCHIRIUS ARENOSUS Steph. (THORACICUS Rossi). Exmouth Warren, Parfitt, not uncommon; de la Garde, three specimens iv/07, common vii/09.

†D. SALINUS Schaum. Exmouth Warren, Parfitt, very rare; de la Garde iv/07 and viii/07. Dawlish, G. C. Champion, August–September, 1907. Par, Vic. Hist. Corn.

*PANAGÆUS BIPUSTULATUS Fab. (4-PUSTULATUS Sturm.). Whitsand Bay, May, 1890, one under stone on the slopes; Tregantle, March, 1905, one. Penlee Point, May, 1902, one running on pathway, E. E. Lowe. Dartmouth, spring, 1908, H. St. J. K. Donisthorpe. Shaldon, April, 1909, one in moss, de la Garde.

*CHLÆNIUS VESTITUS Payk. Slapton Ley; Wembury Beach, June, 1898, several by the rivulet; Lipson Marsh, April, 1900; Compton Fields, 1901. Shaldon, de la Garde, one under the cliff. Has not occurred to me at inland marshes.

*C. NIGRICORNIS F. and var. MELANOCORNIS Dej. Slapton Ley. The latter a single specimen only.

*BROSCUS CEPHALOTES L. Whitsand Bay.

*BEMBIDIUM CONCINNUM Steph. Abundant on the shore near Puslinch, estuary of the Yealm, August, 1900; several examples on the shore, Newton Ferrers, June, 1916; in great abundance in the bed of the river near the mouth of the Tavy, 1917.

†B. SAXATILE Gyll. Shaldon, de la Garde. Exmouth, G. C. Champion.

†B. VARIUM Ol. Downderry, August, 1900; Lipson Marsh, May, 1910.

†B. MINIMUM F. Exminster, Parfitt; muddy places by the Exe. Topsham, de la Garde, April and August, 1912.

†B. NORMANNUM Dej. Wivelscombe Creek, June, 1915, six examples. Dawlish Warren, in numbers, March, 1907, de la Garde (a small form).

†LIMNÆUM NIGROPICEUM Marsh. Rare. Batten, December, 1888, one; August, 1889, one; August, 1890, one; September, 1890, two,

deep in the shingle. Rame Head, April, 1902, three examples. Shaldon, one, de la Garde. Torcross, August–September, 1907, G. C. Champion. Side of the Exe, rare, Parfitt.

‡CILLENUS LATERALIS Sam. Millbrook Creek and mouth of the Yealm, in numbers. Wivelscombe Creek and Bere Ferrers, a few specimens. Dawlish Warren, one example, February, 1908, de la Garde.

†TACHYS PARVULUS Dej. Four specimens, in shingle just below high water, about half a mile beyond Bovisand, June, 1905.

‡AEPUS MARINUS Ström. Generally distributed all along the coast from the Yealm to Cremyll, also found in the estuaries at Wivelscombe, Bere Ferrers, etc. Some seasons abundant. At Batten, October, 1909, quite 200 under one boulder, 70 were captured. Once only I found them in numbers in the roll of rejected seaweed at high-water mark at Millbrook Creek, their usual habitat being under stones embedded an inch or two in clayey shores. They occur practically all the year round and their larvæ may often be taken with them. In 1888 the insect could be obtained at Tinside and in coves between the rocks under the Citadel. Shaldon, de la Garde and G. C. Champion, August-September, 1907.

‡A. ROBINII Laboulb. This species is very like the preceding, but, besides its well-known specific differences, is of more robust build. It occurs all along the coast and may be taken in company with *marinus*, but I have not found it in the estuaries.

In 1889 and 1890 this species occurred to me more commonly than did *A. marinus*.

Probably there are alternating but gradual periods of abundance and scarcity in the occurrence of the two species; and I indeed noted that, in 1909, when *marinus* could be obtained in greater numbers than ever I saw it before, *robinii* did not occur to me at all. It is not easy to appreciate the cause of a definite struggle for existence between these two species, because, although occasionally met with together, the natural habitat of *robinii* seems to be much nearer the Laminarian zone than that of *marinus*. It was in the domain of the latter species that the submarine Hemipteron *Aëpophilus* was first discovered, and it has always been in that region that I have taken it in any quantity at Batten. In my experience it will be only by the lucky capture of stray individuals that *Aëpophilus* will be obtained where *marinus* abounds, i.e. in the upper reaches of the shore, below high-water mark.

NOTE.—Professor Miall, in his Natural History of Aquatic Insects, 1895, p. 376, speaking of *Aëpus*, says: " The eyes are very curious. A chitinous plate protects and almost entirely covers them, leaving only a small round central hole. The form of this plate suggests that it may be employed as a kind of pin-hole camera. Mr. Hammond, who called my attention to this peculiarity, has drawn it in Fig. 114." I have never been able to find this protecting cover to the eyes in any of the Plymouth examples, and recently (in 1916) I called the attention of my friend, Mr. R. J. Baker, to the subject. He dissected out the eyes of several specimens and very soon presented me with a pin-hole plate mounted in balsam on a slide. At the same time he called my attention to the fact that this plate was at the back of the eye and not in front, as the description in Miall would lead one to suppose; and pointed out that the illustration of the eye in section in the work in question depicted the plate at the extreme back of the eye. If, therefore, Mr. Baker is right in assuming the drawing to be correct and the text not so, the supposed curiosity is nothing more than the ordinary optic foramen found probably in all beetles with organs of vision.

*PERILEPTUS AREOLATUS Creutz. Two specimens, Stoke Bay, June 10th, 1917, in shingle by a rill of fresh water. It was in quantity, but I did not recognize it. July 15th, very scarce at the rill, but I discovered it in numbers nearer the sea, where the shingle ended and the rocks commenced, by throwing the shingle into pools formed by the rill, and in which the seaweed *Enteromorpha intestinalis* (kindly named for me by Mr. T. V. Hodgson) was growing. This species is not usually considered a coast insect, but its occurrence under the conditions noted appears to warrant its inclusion in this list. Dr. Cameron, R.N., tells me that "*Perileptus* is common in shingle stream banks in the Eastern Mediterranean right down to the coast." The beetle is rare in England.

†TRECHUS FULVUS Dej. (LAPIDOSUS Daws). Three specimens on the beach at Rame Head, April, 1902; one, Bovisand, July, 1905.

*T. SUBNOTATUS Dej. Introduced by Mr. Newbery as British on a single specimen taken by de la Garde, at Shaldon. The insect was shaken out of a tuft of grass evidently dislodged from the cliffs and lying on the beach. Ent. Mo. Mag., Vol. XLVI. (1910), p. 131.

†POGONUS CHALCEUS Marsh. Mouth of the Erme, September, 1906; Wivelscombe Creek, June, 1915; Budshead Creek, Tamerton, June, 1916. Dawlish Warren, abundant, de la Garde.

*HARPALUS TENEBROSUS Dej. This rare species was first discovered in the Plymouth district by Mr. J. J. Walker at Whitsand Bay in 1875, who showed me the exact locality, where it may still be obtained in spring and autumn. Batten, one male, April, 1904. Slapton Ley, Wollaston, 1852.

*H. TARDUS Panz. Mothecombe, September, 1905, three females. Dawlish, de la Garde.

*H. ATTENUATUS Steph. One specimen, Whitsands, June, 1902, but abundant in the following August. One only Millbrook Creek, July, 1902. Dawlish Warren, April, 1907, one only, de la Garde.

†DICHIROTRICHUS OBSOLETUS Dej. Three near Cargreen in rejectamenta on the shore, October, 1912.

†D. PUBESCENS Payk. Near mouth of the Erme, September, 1906, in abundance. Cargreen, October, 1912, one only. Wivelscombe Creek, June, 1915, several. Dawlish, de la Garde.

*AMARA OVATA F. Whitsand Bay, not rare. Downderry, E. A. Newbery. Woodbury Common, scarce, Parfitt.

Ab. ADAMANTINA Kol. Tregantle, one specimen, August, 1902. Apparently the only British record of this brilliant variety.

*A. LUCIDA Duft. Whitsand Bay. Frequent.

*CALATHUS MOLLIS Marsh. Torcross, August, 1895. Dawlish, de la Garde.

†LIONYCHUS QUADRILLUM Duft. The first record of this rare species for Devonshire was made by Mr. T. V. Wollaston, who discovered it at Slapton Ley. In The Zoologist, 1851–2, p. 3619, he says: "Its habits are very remarkable . . . it selects the driest and most barren shingle at a distance from the beach, so loose and bare that even weeds are unable to exist upon it—where the insect may be seen darting from beneath in the clear sunshine, and as suddenly disappearing. . . . It is difficult to speculate on what a voracious insect like the present can feed in such a position; for the smaller animals in a pebble ridge, so dry and shifting as to refuse nourishment to even a blade of grass, and having more the appearance in fact of a recently opened gravel-pit than anything else, cannot be very numerous." I have several times searched for the insect in the shingles on the marine side of the Ley in vain; but I have taken it on two or three occasions in the shingle, close up to the rocks on the shore from Torcross to the Beesands, in the months of August and May. The examples were almost entirely the aberrant forms, none was a well-marked typical *quadrillum*.

In May, 1915, I discovered *Lionychus* at Downderry, Cornwall, darting about amongst the shingle at the foot of the sloping slaty rocks at high-tide mark. Seven typical forms, six with the posterior pair of spots very small, one with the latter just discernible, and two aberrations were taken. Remembering Wollaston's remarks, I watched the behaviour of the insects very carefully. They not only appeared and disappeared with rapidity in the gravel, but also darted about like flashes of light in the sunshine on the rocks close above it. When hard pressed in the chase, they made for joints in the slate in a way which convinced me they were quite familiar with the shelter to be obtained between the layers; and it was not always easy to dislodge them without injury when once they had reached their goal. It was not convenient for me to visit this locality again until August, 1916, when a most careful and prolonged search for some hour and a half failed to reveal a single specimen; but, by opening up the lamellæ of the slate rock below high-tide mark, I secured some half-dozen mature examples. There is little doubt that these specimens had bred there.

Ab. BIPUNCTATUS Heer. Slapton, Wollaston; Torcross; Downderry.

Ab. UNICOLOR Schill. Torcross.

*MICROLESTES (BLECHRUS) MAURUS Sturm. Bovisand; Wembury; Whitsands.

*DROMIUS NIGRIVENTRIS Thoms. Dawlish, May, 1906, one only.

*D. VECTENSIS Rye. On the shore between Torcross and Beesands, one only, May, 1901; at roots same locality, G. C. Champion and myself, about a dozen examples, August, 1907. Seaton, Power.

HYDRADEPHAGA.

*CŒLAMBUS INÆQUALIS F. Common. Lipson Marsh; Chelson Meadows; Downderry; Slapton Ley.

*BIDESSUS MINUTISSIMUS Germ. Slapton Ley, in quantity at times. First recorded by Wollaston.

*HYDROPORUS (DERONECTES) ASSIMILIS Payk. Slapton Ley, de la Garde one only, October, 1907.

*H. LINEATUS F. Exminster, de la Garde.

*AGABUS CONSPERSUS Marsh. Plentiful in a pool by the mouth of the R. Seaton, near Downderry.

*GYRINUS ELONGATUS Aubé. Slapton Ley.

*G. MARINUS Gyll. Powderham, Parfitt.

PALPICORNIA.

†HELOPHORUS MULSANTI Rye. In numbers by the R. Teign, near Teignmouth, June, 1909, de la Garde and myself.

†OCHTHEBIUS MARINUS Payk. In numbers in salt marsh, Insworke Barton, near Millbrook, June, 1909; Slapton Ley, April, 1913. By the R. Teign, de la Garde.

*O. VIRIDIS Peyr. Botusfleming, one specimen, ex coll. Rev. T. A. Marshall. Downderry, in swarms, edges of muddy pool, August, 1900; again in August, 1916.

†O. LEJOLISI Muls. et Rey. In brackish pools on the rocks between Penlee Point and Rame Head, 55 specimens, September, 1901.

*O. PYGMÆUS F. Slapton Ley, April, 1897, in abundance; by the Teign, June, 1909, one only.

*O. IMPRESSICOLLIS Lap. (BICOLON Steph.). Lipson Marsh, May, 1899, one only, May, 1910, in swarms; Chelson Meadow, August, 1907; May, 1908, one specimen caught in sweep net, Cawsand to Rame. By the Teign, abundantly, de la Garde.

*O. METALLESCENS Rosenh. *var.* POWERI Rye. Seaton, Dr. Power, one specimen, the original capture of this species. One specimen only, in fresh-water trickle on face of rocks on the shore at Bovisand, July, 1912. Subsequent search has failed, both in spring and autumn. Exmouth district, G. C. Champion, a single example in the summer of 1915; later in the year, having discovered the habits of the insect, he took it in some numbers. *Vide* Ent. Mo. Mag., Vol. LI., pp. 309–10.

*LACCOBIUS PURPURASCENS Newbery. Discovered by de la Garde, May, 1906, crawling in swarms among the slimy ooze where water had trickled down the red sandstone cliffs at Shaldon. Exmouth, G. C. Champion.

†CERCYON LITTORALIS Gyll. Generally abundant in the line of rejected seaweed at high-tide mark on the shore.

Var. BINOTATUM Steph. Frequent, with the type form.

†C. DEPRESSUS Steph. Found with the above, and not uncommon at Batten and other places in the Plymouth district. De la Garde records it from Shaldon only in the Teignmouth and Dawlish districts.

BRACHELYTRA.

†ALEOCHARA GRISEA Kr. Batten; Jennycliff; Bigbury Bay; Tregantle; Shaldon; but I never met with it in numbers. Dawlish Warren and Shaldon, de la Garde.

†A. ALGARUM Fauv. Common in decaying seaweed all around the coast.

†A. OBSCURELLA Er. With the above, but not so common.

*Oxypoda exoleta Er. Downderry, October, 1900, a single specimen.

‡Heterota (Alianta) plumbea Wat. Under seaweed; occurs with us from Wembury to Tregantle, but is not common. Exmouth, very rare, Parfitt. Shaldon, de la Garde. Abundant, August–September, 1907, G. C. Champion.

*Atheta thinoboides Kr. (longula Heer). Slapton Ley, in the wet shingle and sand at edge of the water, sometimes in profusion; Wembury beach, several specimens, June and July, 1916; Downderry; Stoke Bay, June, 1917. Mount Edgcumbe shore, E. A. Newbery. Shaldon, de la Garde.

†A. vestita Grav. Very common under seaweed on the coast, and often in the estuaries, in small numbers.

†A. flavipes Thoms. (halobrectha Shp.). Common under seaweed and in shingle.

*A. puncticeps Thoms. (algæ Hardy). A single specimen at Downderry, October, 1900. Shaldon, de la Garde.

*A. triangulum Kr. Slapton Ley; Cremyll; in seaweed. Shaldon, de la Garde.

*A. indubia Sharp. Millbrook Creek, several, May, 1906.

*A. fungi *var.* orbata Er. Burrow Island, May, 1911, one specimen at roots. Dawlish, de la Garde.

†Myrmecopora brevipes. Butl. In seaweed and shingle, generally distributed around the coast, and also in the estuaries; often in quantity. Shaldon and Dawlish Warren, de la Garde. It appears to replace *M. uvida* Er. with us and was considered to be that species until separated by Mr. E. A. Butler, who observes: ". . . the two insects do not overlap, but *M. brevipes* belongs to Devon and Cornwall, while *M. uvida* extends along the rest of the south coast from Hants to Kent and the estuary of the Thames. The area of *M. brevipes* therefore stands at present as Brittany, Jersey and the two south-western counties of England, while *M. uvida* is generally distributed."—Ent. Mo. Mag., XLV. (1909), p. 30.

†M. sulcata Kies. Of similar habit to the above, but occurs in greater numbers.

‡Actocharis marina Fauv. (readingi Shp.). Originally found at Plymouth by Mr. J. J. Reading. I searched in vain for years for it in the Batten district, which I understood was its habitat. It was rediscovered by Dr. M. Cameron at Millbrook Creek, in October, 1900, who obtained several specimens under seaweed. A few days later by carefully examining the shingle we together obtained some

40 specimens. July, 1901, 23 specimens; July, 1902, 9 specimens. The species is gregarious, but its minute size, 1½ mm., makes it easily overlooked. Mr. J. J. Walker has taken it on several occasions at Falmouth.

†SIPALIA TESTACEA Bris. Batten beach under stones below high tide, and Millbrook Creek in the shingle at roots of rushes at high-tide mark. I have taken this rare species from March to September.

‡ARENA OCTAVII Fauv. Dawlish Warren, de la Garde, April, 1907, one specimen under dry tidal rubbish, and a few specimens in later years.

†PHYTOSUS SPINIFER Curt. Tregantle in April and May and again in August, occasionally in considerable numbers; Bovisand, one only, July, 1912, and one only, May, 1913; Stoke Bay, June, 1916, one only. De la Garde, Shaldon, February; Dawlish Warren, April. G. C. Champion, August–September, 1907.

†P. BALTICUS Kr. Under seaweed and in the sand below it with the above species, often in numbers, at Tregantle. Dawlish Warren, plentiful, March, 1907, and later years, de la Garde. August–September, 1907, G. C. Champion.

†P. NIGRIVENTRIS Chevr. With the above at Tregantle, but not so abundant. Dawlish Warren, de la Garde, March, 1907, and later years.

‡DIGLOTTA MERSA Hal. Batten, once only, a single specimen in April, 1892; under stones much below high water, Millbrook Creek, very sparingly, in May, 1900, 1907, 1909. De la Garde has taken it freely at Dawlish Warren. In June, 1909, at the latter locality I obtained a large specimen, 2½ mm. long, possessed of fully developed wings, the length of each being 2 mm. with a maximum breadth of 1 mm. Apparently this form is extremely unusual. *Vide* G. C. Champion's remarks thereon, Ent. Mo. Mag., Vol. XXXV., pp. 264–5.

†HETEROTHOPS BINOTATA Er. Jennycliff; Batten; Downderry. Shaldon, de la Garde.

*QUEDIUS UMBRINUS Er. This uncommon species, which Fowler (Col. Brit. Isles, Vol. II., p. 241) says: "Appears to be chiefly found in wooded and hilly or mountainous districts," I once found in considerable numbers at Millbrook Creek in the little salt marsh beyond Palmer's Point in August, 1900. G. C. Champion also records it from damp places on the cliffs, Shaldon (Ent. Mo. Mag., 1908, p. 33).

*Q. SEMIÆNEUS Steph. Slapton; Tregantle; single specimens frequently, Millbrook Creek; by the Yealm. Shaldon, de la Garde.

*OCYPUS ATER Grav. Bovisand; Batten; Millbrook Creek, in some numbers; Tregantle. Shaldon, de la Garde. Looe, Vict. Hist. Corn.

*PHILONTHUS CRUENTATUS Gmel. Batten and probably all along the coast.

*P. PUNCTUS Grav. Slapton Ley (where it was first discovered by Mr. Wollaston) in May and June, in sundry years. G. C. Champion, August–September, 1907, very rarely. Mr. Bridgman's record in Fowler is an error, although he looked for it continuously for some years, as he told me, *in lit.*, Oct., 1897.

†CAFIUS FUCICOLA Curtis. In decaying seaweed; as a rule, local and rare; abundant with us at Batten and Jennycliff, Millbrook Creek, Tregantle. Dawlish district, one record by Mr. Rendel. A large-headed form of the male occurs commonly. In fine specimens the head is as wide as apex of elytra.

†C. XANTHOLOMA Grav. All around the coast, very common.

Var. VARIOLOSUS Shp. Not uncommon with the type form in the Plymouth district; Shaldon, de la Garde.

Var. VARIEGATUS Er. Batten, Jennycliff, etc., not uncommon.

†C. SERICEUS Holme. Generally distributed with the above, but much less abundant. Shaldon, de la Garde.

NOTE.—The *Cafii* may be found almost throughout the year and larvæ with them.

*SCOPÆUS MINIMUS Er. (RYEI Woll.). In April, 1897, in numbers at Slapton Ley, its only British locality, under smallish flat stones amongst herbage several yards from the edge of the Ley towards the sea, but I have not again met with it. Mr. Wollaston took it originally in May, 1869. G. C. Champion, August–September, 1916.

†MEDON POCOFER Peyr. Batten, two specimens only; Torcross, one only in May, 1901.

†M. RIPICOLA Kr. Batten, July, 1890, two in February, 1897, and in the following May I secured it in quantity in rotting seaweed at Jennycliff; August, 1902, one only on the beach beyond Bovisand.

*ASTENUS (SUNIUS) FILIFORMIS Latr. Whitsand Bay, single specimens occasionally; Tregantle; Downderry, August, 1900, six examples, and at various times since; Bigbury Bay, two specimens, May, 1911. Dawlish, one only, de la Garde.

*STENUS ATRATULUS Er. Downderry, August, 1905, E. A. Newbery and myself.

†BLEDIUS SPECTABILIS Kr. One specimen, Dawlish, de la Garde.

†B. UNICORNIS Germ. Dawlish Warren, de la Garde.

†B. SECERNENDUS Joy. Dawlish Warren, in quantity, de la Garde. This species appears in our latest List as a synonym of the var. *subniger* of Schneider, but as he considered his insect to be nothing more than a monstrosity, Joy's name must probably stand.

NOTE.—It is apparently strange that in the immediate neighbourhood of Plymouth the genus *Bledius* should be unrepresented. *Dyschirius*, which preys upon the larvæ and pupæ of *Bledius*, is, however, also as far as I can discover almost absent, its sole exponent being the widely distributed and common little *D. globosus*. Suitable habitats both on the coast and in the estuaries are still perhaps awaiting investigation.

†OXYTELUS PERRISI Fauv. (MARITIMUS Thoms.). In spring and autumn at Tregantle. First taken there by Mr. J. J. Walker. In May, 1902, the *var.* with testaceous elytra occurred in some numbers. Dawlish, de la Garde.

*O. COMPLANATUS Pand. Batten, Millbrook, etc.

‡TROGOPHLŒUS HALOPHILUS Kies. Millbrook Creek, two only, May, 1900; in June, on the South Down side, in numbers; July, 1916, several between lamellæ of slate on the shore, creek at Brixton.

†T. UNICOLOR Shp. (ANGLICANUS Shp.). This species was extra-European, being known from New Zealand only, until I found the first specimen under a stone at about half-tide near Palmer's Point, Millbrook Creek; after much search my second example was found on the opposite bank of the creek, near South Down, in a similar situation. In July Dr. M. Cameron, R.N., captured two specimens in the roll of seaweed at high tide near my original locality, and in August we together took 17 specimens in the seaweed. The insect has persisted in the locality to the present time, occurring frequently in considerable numbers; in July, 1905, for example, it was swarming, and I secured 180 specimens in an hour and a half! My second specimen, noted above, cost me 40 hours' work grubbing for it!

There was considerable difference of opinion amongst authorities as to the probable origin of this Staphylinid in England. M. Fauvel held that the species was identical with that from N.Z. Dr. D. Sharp inclined to the "opposite opinion, and to the conclusion that we have here to do with two species almost identical in structure and general character, produced independently in the two antipodes of the world, but under very similar conditions." He also stated: "As, however, *T. anglicanus* belongs to one of the most neglected and unattractive groups of Coleoptera, I shall not be surprised to hear of its discovery elsewhere on the coasts of Western Europe" (*Vide* Ent. Mo. Mag., Vol. XXXVI., pp. 230 *et seqq.*). In 1908 Mr. Horace Donisthorpe recorded the capture of two examples of this species, one under seaweed at Bembridge and another on the sea wall at St. Helens, Isle of Wight (Ent. Mo. Mag., Vol. XLIV., p. 255).

*LESTEVA FONTINALIS Kies. First discovered by de la Garde in wet moss on the face of the cliffs at Shaldon in February, 1908, and added to the British List by Newbery (Ent. Mo. Mag. XLVI (1910), p. 109). Exmouth, July–August, 1916, G. C. Champion.

‡MICRALYMMA MARINUM Stroem. (BREVIPENNE Gyll.). Yealm, Batten, Millbrook Creek, and Wivelscombe; one specimen by the R. Teign in June, 1909. In July, 1897, at Batten with Mr. Newbery and his nephew, the latter called attention to *Micralymma* crawling amongst the Acorn Barnacles, and by scraping these off the rocks we secured a considerable number of the beetle. In June, 1900, at Millbrook Creek, I took 20 examples, with *Podura maritima*, between slates used in an old landing-stage. Again at Batten in September and October, 1907, I found *Micralymma* with larvæ and numbers of *Poduræ* by scraping off the rocks little patches of lichen (*Lichina pygmæa*—teste E. M Holmes). There is considerable superficial resemblance between *Micralymma* and *Podura*, and as they are so commonly found in association, it would be interesting to ascertain the reason.

†HOMALIUM LÆVIUSCULUM Gyll. Seaweed, common.

†H. RIPARIUM Thoms. With the above, common.

CLAVICORNIA.

*ABLATTARIA (SILPHA) LÆVIGATA F. Bovisand; Tregantle, at roots. I have found it in single specimens only.

†BRACHYGLUTA (BRYAXIS) WATERHOUSEI Rye. Slapton Ley: in rejectamenta on the shore near Cargreen, October, 1912. On the shore, Hooe Lake, near Radford, A. V. Mitchell.

†PTENIDIUM PUNCTATUM Gyll. Generally distributed from Bigbury Bay to Downderry, in great profusion at times under large stones on or close to decaying seaweed, at Batten in particular. Dawlish Warren, de la Garde.

*CORYLOPHUS SUBLÆVIPENNIS Duv. One specimen only at roots in the sand, Downderry, August, 1905. Slapton, August–September. 1907, G. C. Champion.

*MICRASPIS 16-PUNCTATA L. Wivelscombe Creek, June, 1915. The only locality in the Plymouth district at which this species has occurred to me. Dawlish, de la Garde.

*SUBCOCCINELLA (LASIA) 24-PUNCTATA. Frequently met with on the coast, but in August, 1916, I found it in numbers, both pupæ and mature insects, at the roots of *Silene* on the shore at high-tide mark at Downderry.

*CARCINOPIS MINIMA Aubé. Slapton Ley in April, 1900, and May, 1901, by sifting debris near the water's edge.

†PACHYLOPUS (SAPRINUS) MARITIMUS Steph. Tregantle under seaweed and in the sand, sometimes in numbers. Dawlish Warren, de la Garde.

†ACRITUS PUNCTUM Aubé. Tregantle, in May, 1902, in some numbers; of late years single specimens only have occurred to me. First taken there by J. J. Walker. Exminster, one example, de la Garde.

*MELIGETHES EXILIS Sturm. Tregantle, on *Armeria*, etc. First taken there by J. J. Walker.

*CORTICARIA CRENULATA Gyll. Batten, at roots on the beach, once only; abundant at Slapton Ley. Dawlish, de la Garde.

*C. IMPRESSA Ol. (DENTICULATA Gyll.). Penlee Point, on gorse attacked by the dodder, May and June, 1910; Whitsand Bay, Slapton Ley, Dawlish.

*DERMESTES UNDULATUS Brahm. Slapton Ley, not uncommon at times in small carrion.

*GEORYSSUS CRENULATUS Ross. (PYGMÆUS F.). In the trickles of water in the cliff face, July–August, 1916, Exmouth, G. C. Champion.

†HETEROCERUS FLEXUOSUS Steph. Exmouth Warren, Parfitt, rare; Dr. Allen, July, 1900.

*H. FENESTRATUS Thun. (LÆVIGATUS Pz.). Slapton Ley, August, 1895, and June, 1897.

LAMELLICORNIA.

*APHODIUS NITIDULUS F. Dawlish Warren, rare, Parfitt. Whitsands, near Rame, in numbers, July, 1890; very abundant, July, 1899.

*PSAMMOBIUS PORCICOLLIS Ill. Tregantle, apparently the only British locality, where the species was discovered by J. J. Walker. I have obtained it in March, August, and September in various years.

†ÆGIALIA ARENARIA F. Whitsands, not common. Dawlish Warren, a single specimen, de la Garde. Exmouth Warren, "plentiful in dung of animals, etc.," Parfitt.

MALACODERMATA.

*PSILOTHRIX CYANEUS Ol. (NOBILIS Brit. Cat.). Slapton Ley, often in abundance.

PHYTOPHAGA.

*CHRYSOMELA BANKSI F. Generally distributed throughout the Plymouth district.

*C. HÆMOPTERA L. Whitsand Bay.

*PSYLLIODES MARCIDA Ill. Bovisand; Tregantle, on *Cakile maritima*. First discovered there by J. J. Walker. Dawlish Warren, a single specimen, de la Garde.

*CASSIDA VITTATA Vill. Millbrook Creek, one only, May, 1900. Exmouth, Parfitt.

*C. NOBILIS L. On July 21st, 1917, A. V. Mitchell took a specimen of a Cassida apparently referable to this species on the underside of a pebble amongst low plants on Wembury Beach, just at high-tide mark but well within range of a stormy sea, and on showing it to me we together searched carefully for some considerable time, eventually securing about a dozen specimens each as well as the fully fed larvæ and pupæ. Dwarfed plants of a species of Atriplex seemed to me to be a likely food plant, and the perfect insects ate this quite readily in captivity until the end of September, when they ceased feeding, and at the time of writing are resting on the sides of the plaster cage in which they are confined.

RHYNCOPHORA.

*APION LÆVICOLLE Kirby. Whitsands, April, 1900. Bank of the Exe, near Topsham, two specimens, August, 1912, de la Garde.

*APION SCHÖNHERRI Boh. One specimen, Bovisand, July, 1902.

*A. ONONICOLA Bach. (BOHEMANNI Thoms.). On *Ononis*, Tregantle, August, 1902, several examples.

*A. CONFLUENS Kirby. Tregantle, J. J. Walker, on *Matricaria* on the slopes above high-water mark. I have occasionally taken it in numbers.

*A. HOOKERI Kirby. With us on the coast only, on *Matricaria*.

*A. ATOMARIUM Kirby. Whitsand Bay, J. J. Walker, at roots of thyme, sometimes in quantity.

*Otiorrhynchus atroapterus De G. Bigbury Bay, May, 1911. Dawlish Warren, de la Garde.

*O. rugifrons Gyll. Batten, single specimens in July, 1890, and June, 1895; Tregantle, often in numbers. Dawlish, April, 1895, J. J. Walker; one, de la Garde, June, 1907. Torcross, G. C. Bignell, May, 1885.

†Polydrusus chrysomela Ol. Several examples, Wivelscombe Creek, 10th June, 1915, by sweeping the banks just above high water. The specimens were rather abraded.

*Cneorrhinus plagiatus Schall. (geminatus Fab.). Burrow Island, May, 1911, in abundance, but did not find it on the mainland; Tregantle, common. Dawlish, de la Garde.

*Sitones waterhousei Walt. Batten, at roots of low plants, September, 1897; near Yealmpton, May, 1911; Whitsand Bay, frequently, in spring and autumn. First recorded therefrom by J. J. Walker.

*Gronops lunatus L. Dawlish Warren, de la Garde, one example, August, 1908. Woodbury Common, July–August, 1916, G. C. Champion.

*Tychius schneideri Herbst. Recorded in Fowler's Col. Brit. Is. as occurring at Whitsand Bay.

*Rhinocyllus conicus Fröh. Seaton, Major J. N. Still, May and June, 1895, on the slender thistle (*Carduus pycnocephalus*) in some numbers, but in a very restricted area.

*Smicronyx jungermanniæ Reich. Abundant in some years on the dodder of the gorse at Penlee Point, in May and June; also at Tregantle.

*Sibinia sodalis Germ. Dawlish, on flowers of *Armeria*. First discovered there by Felix A. Newbery, and afterwards taken in some numbers by de la Garde.

*Mecinus circulatus Marsh. Tregantle, at roots of low plants in April and May in various years. First recorded therefrom by J. J. Walker.

*Ceuthorrhynchus terminatus Herbst. Bovisand, August, 1902, one specimen at roots on the shore; one specimen, Tregantle, June, 1905. Shaldon, de la Garde.

*C. dawsoni Bris. Bovisand, Batten, Whitsands; often in abundance on *Plantago*.

†Limnobaris t-album L. This weevil is not a recognized salt-marsh species. Fowler says (Col. Brit. Is., Vol. V., p. 379): "Marshy places on aquatic plants; also by general sweeping; local but not uncommon in many districts." It has occurred to me in some

numbers at Wivelscombe Creek, June, 1915, and on the shore at Bere Ferrers, June, 1916, by sweeping sedges, etc. As both of these localities would be covered with salt water for a brief period at spring-tides, and as there are as yet no other records of the capture of this species in Cornwall or Devon, its habit with us seems to render its inclusion in our list desirable.

†CODIOSOMA SPADIX Herbst. Batten, in an old wooden pile on the shore, May, 1892; South Down, in old piles stuck into the mud flats, larvæ and perfect insects in numbers, May, 1909.

NOTE.—In July, 1917, amongst a considerable quantity of beetles collected at random, by my friend Mr. N. Micklewood, in the Lizard district, where he was spending a holiday, and given to me, I detected an example of a *Cathormiocerus* which will probably prove to be new to Britain. The species cannot unfortunately at present be determined, but the insect has been submitted to Mr. G. C. Champion, who observed, "It is certainly a *Cathormiocerus*. . . . It seems to come nearest to *curviscapus* Seidl. The thorax is abnormally shaped and vestiture (except setae) abraded, so I doubt if you will make much of it." Further examples of the Weevil are therefore desirable.

HETEROMERA.

*CRYPTICUS QUISQUILIUS L. Lizard district, July, 1917, several specimens, collected by N. Micklewood.

*PHYLAN (HELIOPATHES) GIBBUS F. Whitsand Bay, frequent. Dawlish Warren, de la Garde.

*HOPATRUM SABULOSUM Gyll. Whitsands; Downderry.

*MICROZOUM TIBIALE F. Looe, —. Thomas, Vic. Hist. Corn.

†PHALERIA CADAVERINA F. Tregantle, often abundant; Downderry. Dawlish Warren, three examples, April, 1907, de la Garde.

*CTENIOPUS SULPHUREUS L. Budleigh Salterton, July–August, 1916, G. C. Champion. Plentiful in the Lizard district and about Hayle. Vic. Hist. Corn.

*ANONCODES (NACERDES) MELANURA Schmidt. Cattedown, one specimen, caught in the road; three specimens bred from old timber from a cellar at Stonehouse.

*MORDELLISTENA PARVULA *var.* INÆQUALIS Muls. Tregantle, July, 1900, three specimens.

†ANTHICUS ANGUSTATUS Curt. Bigbury Bay, April 1st, 1907, abundant under seaweed at high-tide mark, under stones and in the sand; I obtained 96 specimens. In the shingle, Blackpool, Slapton, August–September, 1907, G. C. Champion.

A Trematode Larva from Buccinum undatum and Notes on Trematodes from Post-Larval Fish.

By Marie V. Lebour, D.Sc.
Naturalist at the Plymouth Laboratory.

With Figures 1 to 7 at the end.

On May 30th, 1916, a number of large *Buccinum undatum* were brought in from the trawling grounds; 40 of these were examined and 34 were found to contain larval Trematodes. Another lot in the spring of 1917 contained about the same percentage of infected Mollusks. Two species of Trematodes were present, both contained in the digestive gland, which was absolutely riddled with them.

The first, which was in 4 out of 40 *Buccinum*, was identified as *Cercaria neptuni* Lebour (1912), previously found in both *Neptunea antiqua* and *Buccinum undatum* from the Northumberland coast. This is a thick-tailed cercaria contained in long colourless rediæ which are tightly packed in the digestive gland and give to this organ a characteristic sickly grey appearance quite unlike its ordinary healthy state, so that infected specimens can easily be recognized by cutting a small aperture in the spire of the shell and examining the portion of digestive gland exposed. The further life history of this cercaria is unknown.

The second species occurs much more commonly and was found in 30 out of 40 *Buccinum* examined. The colour of the infected digestive gland is this time an unhealthy pinkish yellow, which is characteristic. The cercariæ are contained in sporocysts which occupy almost the whole of the spire of the shell.

The anatomy of this cercaria shows it to be almost certainly a larval stage of *Zoogonus viviparus* (Olsson), the life history of which is so far unknown (Odhner, 1902). This Trematode in the adult state lives in the intestine of many common fish. It has been recorded from 11 different species, 9 of which are from the Channel—*Zeus faber*, *Blennius gattorugine*, *Blennius ocellaris*, *Solea vulgaris*, *Solea variegata*, *Pleuronectes limanda*, *Pleuronectes microcephalus*, *Pleuronectes platessa* and *Callionymus lyra*. Nicoll (1914) regards *Callionymus lyra*, *Pleuronectes* spp. and *Solea* spp. as undoubtedly their chief hosts, all of these being common on the trawling grounds where the *Buccinum* were caught.

An intermediate host has not yet been identified, but from the structure of the cercaria, which is able to modify the posterior end of its body as a sucker-like organ, it is probable that the intermediate host is an actively swimming animal, as in all probability the sucker is used by the cercaria for fixing the hind end of its body whilst the free part waves about in order to catch a host. The stylet on the head and its glands opening beside it show that the cercaria bores into its host.

STRUCTURE OF SPOROCYST AND CERCARIA.

The sporocyst is faintly yellow in colour and measures from 0·5 to 1 mm. in length and is from 2 to 4 times as long as it is broad. Inside the sporocyst are germ cells and cercariæ in various stages, from 1 to 8 in each sporocyst (Fig. 1).

The full grown cercaria is colourless and transparent, measuring 0·33 mm. to 0·48 mm. in length according to the extent of contraction or expansion (Figs. 2 and 3). The anterior end is rather more rounded than the posterior end and usually the greatest width is in front of the oral sucker, although when the body is greatly extended the width is nearly equal for the whole length, a great amount of extension being possible. The oral sucker is a little more than half the width of the ventral sucker. Oral sucker 0·06 mm., ventral sucker 0·10 mm. Both are well developed and conspicuous. The whole surface of the body is covered with minute spines which enlarge towards the posterior end and are greatly elongated round that portion which is capable of forming the round disc in the middle of which opens the excretory bladder. The posterior end can, however, change its shape so that the disc is not always present (Fig. 6).

The oral sucker bears at its anterior end dorsally a thick stylet, 0·015 mm. long, with a long central and two small lateral points. On each side of the spine opening dorsally are situated a pair of long curved ducts (Fig. 5) connected with a mass of large gland cells on each side, the stylet glands, which occupy the space between the oral and the ventral sucker. The oral sucker has a large circular aperture ventrally placed near the anterior end of the body which leads to a short pre-pharynx, which in the expanded state may be as long as the pharynx but is usually much shorter. Then follows a conspicuous muscular pharynx, 0·03 mm. long, a thin-walled œsophagus and short intestinal diverticula reaching to about the centre of the ventral sucker. In transverse section the tubes of the diverticula are seen to be composed of very few cells, sometimes only two, with large nuclei (Fig. 7).

The ventral sucker is large and muscular with a somewhat oval centre. Immediately behind it and to the sides are the testes, which are well developed compact oval masses of cells with large nuclei. Ovary and vitellaria are not as yet differentiated, although masses of nuclei probably represent these in the process of formation.

The excretory vesicle is an oblong sac with very thick walls composed of large cells. It is conspicuous at the hind end of the body reaching to about the level of the posterior margin of the testes and opening at the extreme hind end in a small papilla.

These features show it to be very like the structure of *Zoogonus viviparus* (see Lebour, 1908), allowing for growth and development especially of the region behind the ventral sucker and of the reproductive organs. The fact also that it is the only really common fish Trematode of these parts with such short intestinal diverticula supports the view. The relationship of this cercaria to the stumpy-tailed forms seems obvious, the stumpy tail in this case being replaced by the peculiar sucker-like disc. The thick-walled excretory vesicle is common to this species and to all in the group and also the boring spine and glands. Except for the peculiarly modified hind end it fits very well into Dollfus' group (1914) of Cotylocercous cercariæ, which are all developed in sporocysts in marine gastropods. None of their life histories are so far known.

I have to thank my colleague, Miss G. E. Webb, for making the sections which were used in working out the structure of the cercaria in order to determine points not easily seen in the living material.

TREMATODES IN POST-LARVAL FISH.

Whilst investigating the food of young fish a number of Trematodes were found. Some of these were immature, others adult and containing ova. Those most frequently found were *Derogenes varicus* and *Pharyngora bacillaris*. *Derogenes varicus* is a common parasite of many fish, notably the Pleuronectids, and in an immature state was found in several fish, particularly *Arnoglossus* and *Scophthalmus norvegicus*. The only intermediate hosts so far known for this species are *Sagitta* and *Harmothoë*, so it is somewhat difficult to say how the worm enters the small fish as they almost certainly do not eat these worms. The most likely explanation seems to be that by the death of the worm host the young Trematode is set free and is then swallowed along with other food by tiny fish in which it afterwards matures.

Derogenes varicus was found in the following fish:—

Arnoglossus sp.	23	*Solea variegata*	4
Scophthalmus norvegicus	18	*Gadus minutus*	2
Pleuronectes limanda	11	*Gadus merlangus*	1
Pleuronectes microcephalus	4	*Callionymus lyra*	1

Pharyngora bacillaris, which inhabits the Mackerel and a few other fish in the adult state, when immature is found abundantly in the tow-nettings both free and in Medusæ, Ctenophores and *Sagitta*. It is the only common Trematode of the plankton and might easily be swallowed by small fish. It occurred in a few sprats, in 3 *Onos mustela* and in one *Rhombus lævis*.

Podocotyle atomon, another common fish Trematode, occurred in 3 specimens of *Gasterosteus spinachia*, and in all cases contained ova.

An encysted Trematode occurred in the peritoneum of 2 specimens of *Syngnathus rostellatus*.

The Horse Mackerel, *Caranx trachurus*, on one occasion contained a mature Trematode, probably *Lecithaster* sp.

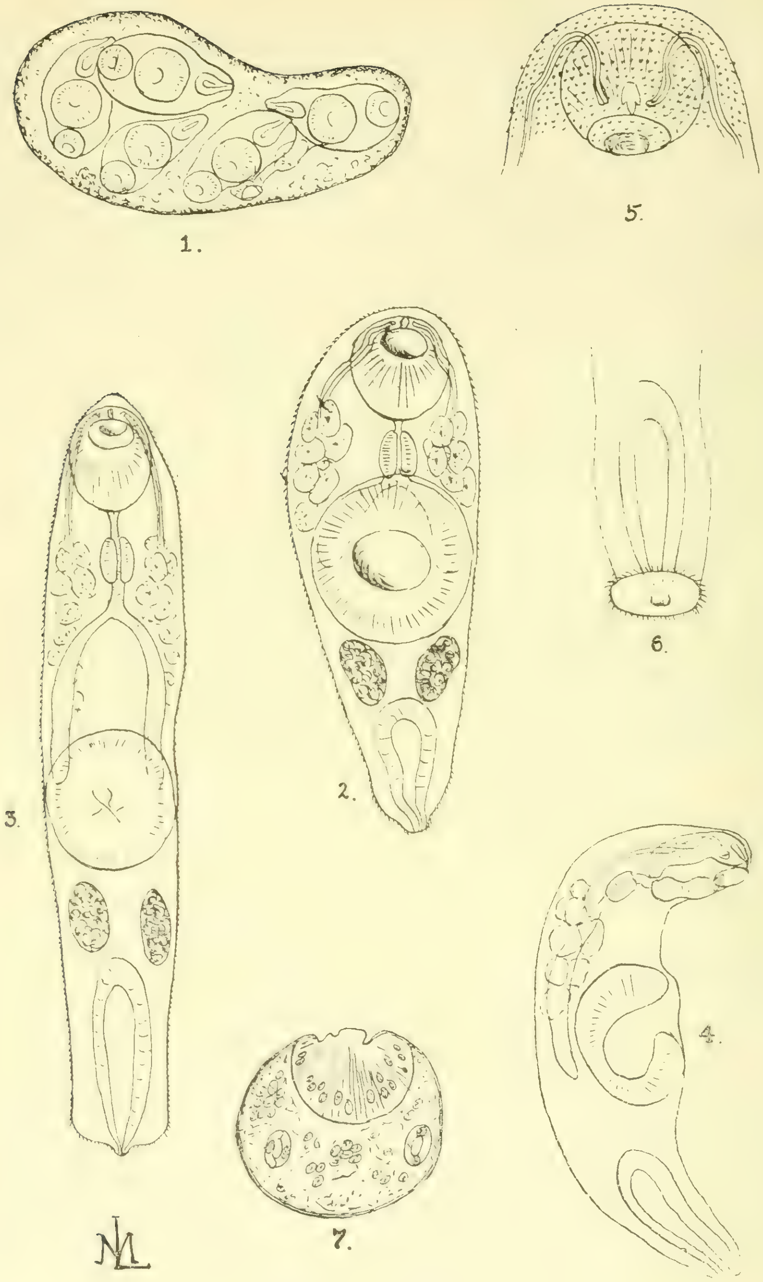
LITERATURE.

1914. *Dollfus, R.* "Cercaria pachycerca Diesing, et les cercaires à queue dite en mignon." IX Congrès Int. de Zool. Monaco.

1908. *Lebour, M. V.* "Fish Trematodes of the Northumberland Coast." North Sea Fish. Rep. for 1907.

1912. —. "A Revision of the Marine Cercariæ." Parasitology, No. 4.

1914. *Nicoll, W.* "The Trematode Parasites of Fishes from the English Channel." Journ. Mar. Biol. Assoc., N.S., X., No. 4.



CERCARIA NEPTUNI Lebour.

EXPLANATION OF FIGURES.

Fig. 1. Sporocyst containing cercariæ from the digestive gland of *Buccinum undatum*
2. Cercaria somewhat contracted.
3. Cercaria expanded.
4. Side view of cercaria.
5. Head of cercaria bent forward to show stylet and glands.
6. Spiny disc at posterior end of cercaria.
7. Transverse section of cercaria through the ventral sucker and intestinal diverticula.

Marine Biological Association of the United Kingdom.

Report of the Council, 1917.

The Council and Officers.

The Council has met four times during the year, the meetings having been held in the Rooms of the Royal Society. The Council desires to express the thanks of the Association to the Royal Society for the accommodation provided. The average attendance at the meetings has been nine, and a Committee of three members of the Council visited and inspected the Laboratory at Plymouth.

The Council has to record with regret the death of the Earl of Portsmouth, who for a number of years was a Governor, representing the Worshipful Company of Fishmongers. Lord Portsmouth showed much interest in the work of the Plymouth Laboratory.

The Plymouth Laboratory.

The new gas-engine supplied last year by Messrs. Crossley Bros., for circulating sea-water through the tanks, has worked smoothly and continuously, but unfortunately has consumed considerably more gas than the old engine. This, at the present high price of gas, has led to a marked increase in our working expenses. With a view to more economical working, it will be advisable, when conditions are more favourable after the war, to reconsider the whole of our pumping arrangements and try to reach greater efficiency.

The Boats.

The steamer *Oithona* has again not been used this year. The vessel, however, has just been requisitioned by the Admiralty for service in connection with the war. What collecting work was possible under the restricted conditions imposed by the naval and military authorities has been done with the eighteen-foot sailing boat *Anton Dohrn*, and many specimens have been obtained from the commercial fishing boats.

The Staff.

The Council regrets that Mr. D. J. Matthews, who has been employed by the Association for part of his time since the International Investigations were transferred to the Board of Agriculture and Fisheries in 1910, left the service of the Association early in the year.

Miss M. V. Lebour has been granted the degree of D.Sc. by the University of Durham, and has been appointed a permanent member of the Laboratory staff.

Miss G. E. Webb, of Oxford, has been appointed an Assistant Naturalist for the duration of the war, and commenced work at the Laboratory in August.

Messrs. E. W. Nelson, L. R. Crawshay, J. H. Orton, R. S. Clark, and E. Ford are still serving with H.M. Forces.

Occupation of Tables.

The following Naturalists have occupied tables at the Plymouth Laboratory during the year :—

W. De Morgan, Plymouth (Pomatoceros).
Mrs. E. W. Sexton, Plymouth (Gammarus).
Dr. C. Shearer, F.R.S., Cambridge (Dinophilus).

The Easter Vacation Course in Marine Biology for University students was not held this year.

General Work at the Plymouth Laboratory.

Dr. Allen, the Director of the Plymouth Laboratory, has been engaged during a considerable part of the year in carrying out special experiments for the Admiralty Board of Invention and Research. Since his return to the Laboratory he has been continuing his work on the conditions necessary for the successful growth and reproduction of certain marine plants and animals under experimental conditions.

Following on her researches on the plankton and microplankton of the Plymouth district, Dr. Lebour has made the central feature of her work for the year a study of the food actually eaten by fishes in their larval and youngest stages. This is a subject which has been but little studied and results of great interest have been obtained. A report on these appears on page 433. General work on the plankton has also been continued by Miss Lebour, who has been assisted in this by Miss Webb.

Two numbers of the Journal have been published during the year. The first, which was issued in May, contained three papers by Miss Lebour on the microplankton of Plymouth Sound, on the Peridiniales of Plymouth and on some parasites of Sagitta. The first of these papers contained the results obtained from the examination of centrifuged samples of sea-water taken at regular intervals during one complete year, so that seasonal variations are shown. In the same number appears Dr. Allen's report on the larval and young stages of fishes collected during the summer of 1914, this report being a continuation of work carried out for 1913 by Mr. R. S. Clark and reported upon by him in an earlier number of the Journal. Mr. D. J. Matthews contributes the second part of his paper on the amount of phosphoric acid in the sea-water off Plymouth Sound, in which the seasonal variations in the amount of that substance are recorded.

The second number of the Journal, issued in December, contains a detailed report, by Dr. Allen and Mrs. E. W. Sexton, of experiments on the inheritance of eye-colour and the loss of the eye-pigment in the Amphipod *Gammarus chevreuxi*. Three papers of a general character by Dr. Allen, in which the results of work done at the Laboratory are set forth in a more popular form, complete the number. These papers are entitled, "Heredity in Plants, Animals, and Man," "Food from the Sea," and "The Age of Fishes and the Rate at which they Grow."

The Library.

The thanks of the Association are again due to numerous Government Departments, Universities, and other institutions at home and abroad for copies of books and current numbers of periodicals presented to the Library. The list is similar to that published in the Reports of Council of former years. Thanks are due also to those authors who have sent reprints of their papers for the Library.

Donations and Receipts.

The receipts for the year include a grant from H.M. Treasury of £500, and one from the Fishmongers' Company (£600). In addition to these grants there have been received Annual Subscriptions (£123), Rent of Tables in the Laboratory, including £25 from the University of London, and £20 from the Trustees of the Ray Lankester Fund (£45); Sale of Specimens (£371) and Admission to Tank Room (£84).

Vice-Presidents, Officers, and Council.

The following is the list of gentlemen proposed by the Council for election for the year 1918–19:—

President.

Sir E. Ray Lankester, K.C.B., LL.D., F.R.S.

Vice-Presidents.

The Duke of Bedford, K.G.
The Earl of Ducie, F.R.S.
The Earl of Stradbroke, C.V.O., C.B.
Lord Montagu of Beaulieu.
Lord Walsingham, F.R.S.
The Right Hon. A. J. Balfour, M.P., F.R.S.
The Right Hon. Austen Chamberlain, M.P.
W. Astor, Esq., M.P.
G. A. Boulenger, Esq., F.R.S.
A. R. Steel-Maitland, Esq., M.P.
Rev. Canon Norman, D.C.L., F.R.S.
Edwin Waterhouse, Esq.

COUNCIL.

Elected Members.

Prof. W. M. Bayliss, D.Sc, F.R.S.
L. A. Borradaile, Esq.
E. T. Browne, Esq.
W. C. De Morgan, Esq.
Prof. F. W. Gamble, D.Sc., F.R.S.
E. S. Goodrich, Esq., D.Sc., F.R.S.
S. F. Harmer, Esq., Sc.D., F.R.S.
E. W. L. Holt, Esq.
Prof. E. W. MacBride, D.Sc., F.R.S.
H. G. Maurice, Esq., C.B.
P. Chalmers Mitchell, Esq., D.Sc. F.R.S.
F. A. Potts, Esq.
C. Tate Regan, Esq., F.R.S.
Prof. D'Arcy W. Thompson, C.B., F.R.

Chairman of Council.

A. E. Shipley, Esq., D.Sc., F.R.S.

Hon. Treasurer.

George Evans, Esq.

Hon. Secretary.

E. J. Allen, Esq., D.Sc., F.R.S.,
The Laboratory, Citadel Hill, Plymouth.

The following Governors are also members of Council:—

G. P. Bidder, Esq., Sc.D.

R. L. Towgood, Esq. (Prime Warden of the Fishmongers' Company).

T. T. Greg, Esq. (Fishmongers' Company).

The Hon. Nathaniel Charles Rothschild (Fishmongers' Company).

George Evans, Esq. (Fishmonger Company).

Prof. G. C. Bourne, D.Sc., F.R.S. (Oxford University).

A. E. Shipley, Esq., D.Sc., F.R.S. (Cambridge University).

Prof. W. A. Herdman, D.Sc., F.R.S. (British Association).

THE MARINE BIOLOGICAL ASSOCIATION

Dr. *Statement of Receipts and Payments for*

	£	s.	d.	£	s.	d.
To Balance from Last Year :—						
Cash at Bankers	927	16	6			
Cash in hand	11	0	2	938	16	8
,, Current Receipts :—						
H.M. Treasury for the year ending 31st March, 1918	500	0	0			
The Worshipful Company of Fishmongers	600	0	0			
Annual Subscriptions	123	6	8			
Rent of Tables (including Ray Lankester's Trustees, £20; University of London, £25)	45	0	0			
Interest on Investments	12	6	4			
,, Deposit	9	16	7	1,290	9	7
,, Extraordinary Receipts :—						
Donation, G. H. Fox	0	10	6			
Naval Bank—Dividend	1	19	10	2	10	4
,, Laboratory Boats and Sundry Receipts :—						
Sales of Apparatus	3	19	4			
,, ,, Specimens	371	4	2			
,, ,, Nets, Gear, etc.	13	4	8			
Other Items		10	0	388	18	2
				£2,620	14	9

The Association's Bankers hold on its behalf £410 14s. 8d. New Zealand 4% Stock, 1943–63.

OF THE UNITED KINGDOM.

the Year ending 31st December, 1917. Cr.

	£	s.	d.	£	s.	d.
By Salaries and Wages—						
Director	300	0	0			
Hydrographer	62	10	0			
Senior Naturalist	51	12	6			
Additional ,,	131	15	6			
,, ,,	165	6	6			
Assistant ,,	13	2	6			
,, ,, (temporary)	12	13	3			
,, ,, ,,	50	7	0			
,, ,, ,,	10	0	0			
Salaries and Wages	127	4	1	1,224	11	4
,, Travelling Expenses				12	12	11
,, Library	42	12	7			
Less Sale of Duplicate	1	6	0	41	6	7
,, Journal	211	10	2			
Less Sales	7	1	10	204	8	4
,, Buildings and Public Tank Room—						
Gas, Water, and Coal	235	17	1			
Stocking Tanks and Feeding	27	8	6			
Maintenance and Renewals	43	0	4			
Rent, Rates, Taxes, and Insurance	47	8	10			
	353	14	9			
Less Admission to Tank Room	84	12	10	269	1	11
,, Laboratory, Boats, and Sundry Expenses—						
Glass, Apparatus, and Chemicals	50	1	1			
Purchase of Specimens	56	4	11			
Maintenance and Renewal of Boats, Nets, etc.	99	9	4			
Boat Hire and Collecting Expenses	6	16	11			
Stationery, Office Expenses, Carriage, Printing, etc.	80	4	6	292	16	9
,, Balance :—						
Cash at Bankers	568	15	10			
Cash in hand	7	1	1	575	16	11
				£2,620	14	9

Examined and found correct,
(Signed) N. E. Waterhouse.
Thomas T. Greg.
J. O. Borley.

3 *Frederick's Place,*
Old Jewry, London, E.C.
31st January, 1918.

INDEX.

A

Ablattaria (*Silpha*) *laevigata*, 509
Acanthochiasma fusiforme, 158
Acartia clausii, 165, 170–8, 438-56
— sp., 436, 437, 457
Acineta tuberosa, 158
Acnanthes longipes, 151
Acritus punctum, 510
Actinocyclus Ehrenbergi, 145
Actinoptychus undulatus, 145
Actinotrocha, 154, 164
Actocharis marina, 505
Ægeon fasciatus, 168
Ægialia arenaria, 510
Aëpophilus, 500
Aëpus marinus, 500
— *robinii*, 500
Agabus conspersus, 503
Agonus cataphractus, 440
Alcyonium digitatum, development of, 258
Aleochara algarum, 504
— *obscurella*, 504
— *grisea*, 504
Amara adamantina, 502
— *lucida*, 502
— *ovata*, 502
Ammodytes sp., 216, 436-56
Ammodytidae collected near Plymouth, 216
Amoebae, 156, 175
Amphiascus similis, 165
Amphidinium crassum, 138, 176, 188
Amphimelissa setosa, 158
Amphiprora maxima, 152
Amphora ostracaria, 152
— sp., 152
Amylax lata, 185
Anaphia petiolata, 169, 176; notes on the life-history, 51
Annelid larvae, 164
Annual Rings in the scales of Plaic and Flounders, 470
Anomalocera Patersoni, 165, 436, 440
Anoncodes (*Nacerdes*) *melanura*, 513
Anoplodactylus petiolatus, 51
— *pygmaeus*, 51
Anthicus angustatus, 513
Apherusa bispinosa, 166
— *Clevei*, 166, 438
— sp., 442
Aphodius nitidulus, 510
Aphya pellucida, 239
Apion atomarium, 511
— *confluens*, 511
— *hookeri*, 511
— *laevicolle*, 511
— *ononicola*, 511
— *schönherri*, 511
Arachnactis Bournei, 162, 175
Arena octavii, 498, 506
Arnoglossus sp., 232, 443, 449, 451; containing Trematodes, 516
Ascaris, 163; in *Sagitta*, 202
Astenus (*Sunius*) *filiformis*, 507
Asterionella Bleakeleyi, 151
— *japonica*, 136, 151, 171–8
Atheta flavipes, 505
— *fungi*, var. *orbata*, 505
— *indubia*, 505
— *puncticeps*, 505
— *thinoboides*, 505
— *triangulum*, 505
— *vestita*, 505
Aurelia sp., 162, 173
Auricularia, 170, 174

Autolytus longiferiens, 163, 170
— *pictus*, 163, 172
— *rubropunctatus*, 163, 170, 172
— sp., 163

B

Bacillaria paradoxa, 152
Balance sheets, 264, 430, 524
Balanus, 166–78, 436–58
Bellerochia malleus, 151
Bembidium concinnum, 499
— *minimum*, 499
— *normannum*, 499
— *saxatile*, 499
— *varium*, 499
Beroë cucumis, 162, 171
Biddulphia, 135, 139, 142
— *alternans*, 151
— *favus*, 151
— *mobiliensis*, 142, 149, 170–5
— *regia*, 149, 170–5, 440
— *sinensis*, 149, 173–5
— sp., 171
Bidessus minutissimus, 503
Bledius secernendus, 508
— *spectabilis*, 507
— *unicornis*, 508
Blenniidae collected near Plymouth, 247
Blennius galerita, 441
— *gattorugine*, 441 ; host of Zoogonus, 514
— sp., 247
— *ocellaris*, host of Zoogonus, 514
Bolina infundibulum, 162, 171, 176
Bopyrina sp., 167
Bongainvillia brittanica, 161
Brachelytra, 504
Brachygluta (Bryaxis) *waterhousei*, 509
Brachyura zoea, 169, 170, 452
Broscus cephalotes, 499
Buccinum undatum containing Trematodes, 514

C

Cafius fucicola, 507
— *sericeus*, 507
— *xantholoma*, 507
— var. *variegatus*, 507
— var. *variolosus*, 507
Calanus finmarchicus, 164, 170–8, 436–55
— stages in the life-history, 1
Calathus mollis, 502
Caligus rapax, 166
Callionymidae collected near Plymouth, 245
Callionymus lyra, 245, 437–42 ; host of Zoogonus, 514 ; of Derogenes, 516
Campylodiscus sp., 152, 458
Cancer pagurus, 168, 173
Candacia armata, 165, 178
Caprella sp., 166
Carangidae collected near Plymouth, 225
Caranx trachurus, 225, 439, 517
Carcinopsis minima, 510
Carcinus maenas, 169, 173, 174
Carteria sp., 155
Cassida nobilis, 511
— *vittata*, 511
Cathormiocerus, 513
Centropages hamatus, 165, 170, 171, 178
— *typicus*, 165–77, 436–56
— sp., 172, 442, 452
Ceuthorrhynchus dawsoni, 512
— *terminatus*, 512
Ceraphilus nanus, 168
Cerataulina Bergoni, 149, 176
Ceratium arcticum, 187
— *bucephalum*, 171, 172, 187
— *furca*, 187
— *fusus*, 138, 139, 170–7
— *macroceras*, 187
— *platycorne*, 187
— sp., 153, 183, 187
— *tripos*, 187
Cercaria neptuni, 514
Cercyon depressus, 504
— *littoralis*, 504
Chaetoceras, 136–49, 171–5
— *boreale*, 148
— *breve*, 148
— *constrictum*, 148, 170, 177
— *contortum*, 148
— *convolutum*, 147, 173, 174
— *curvisetum*, 135–48, 173–8
— *danicum*, 147
— *debile*, 139, 149
— *decipiens*, 139, 148

Chaetoceras densum, 147
— *diadema*, 148
— *didymum*, 143, 177
— *laciniosum*, 148
— *pseudocrinitum*, 139, 148, 175
— *teres*, 148, 173, 174
— *willei*, 148
Chlænius nigricornis and var. *melanocornis*, 499
— *vestitus*, 499
Chrysaora, sp., 162
Chrysomela banksi, 511
— *hæmoptera*, 511
Cicindela germanica, 499
Cillenus lateralis, 500
Cirratulus (*Audoninia*), *tentaculatus*, œcology of, 60
Cirratulus, sp., 163
Cittarocyclis denticulata, 160, 439
— *edentata*, 160
Clavicornia, 509
Clupea sp., 213, 437 ; age and rate of growth, 417
— *harengus*, 457
— *sprattus*, 459
Clupeidae collected near Plymouth, 213
Clytia volubilis, 161, 175
Cneorrhinus plagiatus, 512
Coccosphæra, 436, 455
Cochlodinium helix, 197
— *pellucidum*, 138, 197
— *pulchellum*, 197
Codiosoma spadix, 513
Cœlambus inæqualis, 503
Coleoptera of South Devon and South Cornwall, 497
Coleps, sp., 158
Corticaria crenulata, 510
— *impressa*, 510
Coryceus anglicus, 165, 170–8, 436–58
Corylophus sublævipennis, 509
Corystes cassivelaunus, 169, 173–5
Coscinodiscus, 138, 139, 142, 170, 172, 441–58
— *excentricus*, 145, 173, 174, 440, 442
— *Granii*, 145, 454
— *radiatus*, 145, 173, 174, 440
— *sub-bulliens*, 145
Cosmetira pilosella, 161 ; containing *Anaphia petiolata*, 51 ; *Pharyngora bacillaris*, 57, 160
Cottus bubalis, 440
Crangon vulgaris, 168, 173, 174
Crypticus quisquilius, 513
Crystallogobius nilssoni, 239, 437, 442
Cteniopus sulphureus, 513
Ctenolabrus rupestris, 222
Cyclogaster Montagui, 442
Cyclopteridæ collected near Plymouth, 241
Cyclopterus lumpus, 241, 442, 460
Cyphonautes larva, 164, 170–4

D

Dermestes undulatus, 510
Derogenes varicus, 163 ; in *Sagitta*, 201 ; in fishes, 202, 516
Diatoms, culture of, 385
Dichirotrichus obsoletus, 502
— *pubescens*, 502
Dictyocha fibula, 140, 155, 177, 178
Diglotta mersa, 506
Dinobryon, sp., 155
Dinophysis acuminata, 154, 176, 184
— *acuta*, 184
— *homunculus*, v. *tripos*, 184
— *ovum*, 184
— *rotundatum*, 184
— sp., 176, 437, 455
Diplopsalis lenticula, 185, 437
— *pillula*, 176, 185
Distephanus speculum, 140, 155, 177, 178, 450
Ditylium Brightwelli, 151, 174
Dromius nigriventris, 503
— *vectensis*, 503
Dyschirius arenosus, 499
— *salinus*, 499

E

Echinopluteus, 170, 177, 178
Endeis spinosus, 52
Ephelota crustaceorum, 158
Eucampia zoodiacus, 149
Eupagurus, sp., 168, 175, 442
Euphausicdae, 167
Euplotes sp., 159
— *vannus*, 159

Eurynome aspera, 168
Euterpina acutifrons, 165, 435–58
Evadne Nordmanni, 166, 175, 178, 458
— sp., 436, 455
Exuviella compressa, 184

F

Fishes, age and rate of growth, 399; food of post-larval, 433
Flounders, scale investigations, 470
Food from the sea, 380
Foraminifera, 156
Fragillaria, sp., 151, 450, 451

G

Gadidæ collected near Plymouth, 217; rate of growth, 402
Gadus luscus, 217, 436, 437, 455
— *merlangus*, 217, 437, 454
— *minutus*, 217, 437, 455
— *morrhua*, 454
— *pollachius*, 217, 455
— sp. 438; containing Trematodes, 516
Galathea sp., 168, 173, 174
Gammarus chevreuxi, Mendelian inheritance of eye-colour, 19; loss of eye-pigment, 273
Gasterosteus spinachia, 456; containing Podocotyle, 517
Geodephaga, 499
Georyssus crenulatus, 510
Glenodinium bipes, 138, 176, 184
Gnathia maxillaris, 167
Gobiesocidae collected near Plymouth, 247
Gobiidæ collected near Plymouth, 239
Gobius, sp., 239, 437, 441
Gonyaulax polyedra, 185
— *polygramma*, 185
— *scrippsae*, 185
— *spinifera*, 185, 458
— *triacantha*, 185
Grammatophora serpentina, 151
Gronops lunatus, 512
Guinardia flaccida, 138, 144, 172, 177, 437
Gymnodinium achromaticum, 190
— *filum*, 193
Gymnodinium lunula, 135
— *minor*, 192
— *pseudonoctiluca*, 188
— *rhomboides*, 176, 183, 190
— *teredo*, 188
— *triangularis*, 183, 192
— *viridis*, 189
Gyrinus elongatus, 503
— *marinus*, 503

H

Halcampa chrysanthellum, 162
Halosphæra viridis, 155, 457, 458
Harpacticus uniremis, 436, 442, 443
Harpalus attenuatus, 502
— *tardus*, 502
— *tenebrosus*, 498, 501
Heliozoa, 156
Helophorus mulsanti, 503
Heredity in Plants, Animals and Man, 354
Herrings, researches on races of, 71
Heterocerus fenestratus, 510
— *flexuosus*, 510
Heteromera, 513
Heterota (*Alianta*) *plumbea*, 505
Heterothrops binotata, 506
Hippolyte, sp., 168, 170, 176, 452
Homalium læviusculum, 509
— *riparium*, 509
Hopatrum sabulosum, 513
Hyalodiscus stelliger, 144, 172, 458
Hybocodon prolifer, 161, 174, 175
Hydradephaga, 503
Hydroporus (*Deronectes*) *assimilis*, 503
— *lineatus*, 503

I

Idotea viridis, 167
Idya furcata, 165, 436–42
Infusoria, 158, 160
Isias clavipes, 165, 436

J

Jaxea noctiana, 168

L

Labidocera Wollastoni, 165
Labœa acuminata, 159

Labœa conica, 159
— *spiralis*, 159
— sp., 138, 140, 159, 170, 171
— *strobila*, 138, 159
Labridæ collected near Plymouth, 222
Labrus bergylta, 222, 437–39
— *mixtus*, 222
Laccobius purpurascens, 504
Lachymaria, sp., 158
Lamellicornia, 510
Lauderia, 136, 175, 178
— *borealis* 139, 142, 144, 437
Leander, sp., 167
Lepadogaster candollei, 442
— *gouani*, 443
— sp., 247
Leptocylindrus danicus, 144, 176
— sp., 144
Leptomysis mediterranea, 167
Lesteva fontinalis, 509
Limacina balea, 169, 171
— *retroversa*. See *balea*
Limnæum nigropiceum, 499
Limnobaris T-album, 512
Lionychus bipunctatus, 503
— *quadrillum*, 502
— *unicolor*, 503
List of Members, 266
Lithodesmium undulatum, 142, 151, 171–8
Lithomelissa setosa, 158, 439
Lohmanniella oviformis, 159
Longipedia minor, 165
— *Scotti*, 165, 436, 448
Lophius piscatorius, 249, 440
Lycmophora Lynbergi, 151

M

Macropsis Slabberia, 167
Magelona, sp., 163
Malacodermata, 511
Maritime Coleoptera, 497
Mastigloia, 136, 142, 143, 151, 171–6
Mecinus circulatus, 512
Medon pocofer, 507
— *ripicola*, 507
Medusæ containing Pycnogonids, 51, 160
— as hosts for larval Trematodes, 57, 160
Meligethes exilis, 510
Melosira Borreri, 143
Mendelian inheritance in *Gammarus*, 18, 273, 364; in plants, animals, and man, 354
Mesodinium, sp., 159
Metridia lucens, 436–55
Micralymma marinum, 509
Micraspis 16-*punctata*, 510
Microlestes (*Blechrus*) *maurus*, 503
Microniscus sp , 167
Microplankton of Plymouth Sound, 133
Microsetella norvegica, 436, 448
Microzoum tibiale, 513
Molva molva, 220
Mordellistena parvula, var. *inæqualis*, 513
Muggiæa atlantica, 162, 173–8
Myrmecopora brevipes, 505
— *sulcata*, 505

N

Nassula, sp., 159
Navicula membranacea, 151
— sp., 151, 437–53
Nerophis lumbriciformis, 457
Nitzschia closterium, 135, 139, 152, 171
— *delicatissima*, 135, 136, 139, 142, 152, 175, 176
— *panduriformis*, 152
— *seriata*, 152
Nyctiphanes Couchii, 167

O

Obelia, sp., 161, 170–8; containing *Anaphia petiolata*, 51; *Pharyngora bacillaris*, 57, 160
Ochthebius impressicollis, 504
— *lejolisi*, 504
— *marinus*, 504
— *metallescens*, 504
— *pygmæus*, 504
— *viridis*, 504
Ocypus ater, 507
Oikopleura dioica, 170–8
Oithona nana, 165
— *plumifera*, 165
— *similis*, 165, 173, 436, 458
— sp., 456

Oncœa, sp., 436–58
Onos mustelus, 221, 437, 456; containing *Pharyngora*, 517
Ophiopluteus, 170, 174, 178
Otiorrhynchus atroapterus, 512
— *rugifrons*, 512
Oxypoda exoleta, 505
Oxyrrhis marina, 155, 198
Oxytelus complanatus, 508
— *perrisi*, 508
Oxytoxum Milneri, 186

P

Pachylopus (*Saprinus*) *maritimus*, 510
Pallene brevirostris, 169
Palpicornia, 503
Panagæus bipostulatus, 499
Paracalanus parvus, 164–78, 437–57
Paracineta limbata, 158
Paralia sulcata, 135–42, 170–6, 437–58
Parapontella brevicornis, 165, 173, 174
Peachia sp., 162, 176
Pectinaria sp., 164
Pediculati collected near Plymouth, 249
Peridiniales of Plymouth Sound, 183
Peridinium cerasus, 185, 437
— *conicum*, 186
— *crassipes*, 186
— *divergens*, 171, 186
— *oceanicum*, 186
— *orbiculare*, 185
— *ovatum*, 154, 186, 437–9
— *pallidum*, 154, 186, 437
— *pedunculatum*, 186
— *pellucidum*, 154, 186
— *roseum*, 185
— sp., 153, 154, 175, 176, 183, 437–51
— *Thorianum*, 186
Perileptus areolatus, 501
Phæocystis, 137, 152, 154, 176, 450
— *Pouchetii*, 175, 183
Phaleria cadaverina, 513
Pharyngora bacillaris, 57, 162; in *Sagitta*, 202; in other hosts, 203; in fishes, 517
Phialidium hemisphericum, 161, 170–8
— containing *Anaphia petiolata*, 51; *Pharyngora bacillaris*, 57; *Peachia*, 160
Philonthus cruentatus, 507
— *punctus*, 507
Phosphoric Acid in sea-water, 122, 251
Phylan (*Heliopathes*) *gibbus*, 513
Phytophaga, 511
Phytosus balticus, 506
— *nigriventris*, 506
— *spinifer*, 506
Plaice, scale investigations, 470
Pleurobrachia pileus, 162, 170–3; host of *Pharyngora bacillaris*, 57
Pleuronectes flesus, 443, 450
— *limanda*, 229, 435–50; containing Trematodes, 514, 516
— *microcephalus*, 229, 437, 443, 451; containing Trematodes, 514, 516
— *platessa*, 443; containing Trematodes, 514
Pleuronectidæ collected near Plymouth, 229, 443; age and rate of growth, 404
Pleurosigma sp., 151, 437–51
Podocotyle atomon, in *Gasterosteus*, 517
Podon intermedius, 166–78, 435–55
Poecilochætus serpens, 163, 174
Pogonus chalceus, 501
Polycera quadrilineata, 169
Polychaetes possessing a heart-body, 65
Polydrusus chrysomela, 512
Polykrikos Schwarzii, 198
Polynoë, sp., 163
Polystomella, 156
Pontosphæra Huxleyi, 155, 170, 171
Porcellana, sp., 168–77, 439
Portunus, sp., 169, 174–7
Post-larval Teleosteans collected near Plymouth, 207
Pouchetia armata, 154, 176, 198
— *fusus*, 198
— *parva*, 138, 198
Prorocentrum micans, 135–9, 154, 170–8, 184, 437–57
Protoceratium reticulatum, 185
Psammobius porcicollis, 498, 510
Pseudocalanus elongatus, 164–78, 435–59
Pseudocuma cercaria, 167
Psilothrix cyaneus, 511
Psylliodes marcida, 511

Ptenidium punctatum, 509
Pyrocystis lunula, 139, 198
Pyrophacus horologicum, 186

Q

Quedius semiæneus, 506
— *umbrinus*, 506

R

Raniceps raninus, 220
Rathkea octopunctata, 161, 173, 174
Report of Council, 259, 425, 519
Rhamphistoma belone, 443, 460
Rhinocyllus conicus, 512
Rhizosolenia alata, 139, 142, 170–7
— *hebetata* form *semispina*, 139, 142, 176
— *robusta*, 145, 147
— *setiger* , 142, 147, 177
— *Shrubsolei*, 135–47, 174, 436, 456
— sp., 142, 175–7
— *Stolterfothii*, 139, 142, 146, 170–8
Rhombus lævis, 234, 443, 452 ; containing *Pharyngora*, 517
— *maximus*, 234, 443, 452
Rhyncophora, 511
Roccus labrax, 222

S

Sagitta bipunctata, 164, 170–8 ; parasites of, 201
Saphenia gracilis, 161, 176
Sarsia eximia, 161
— *prolifera*, 161
— *tuberosa*, 161
Scomber scomber, 226, 439 ; rate of growth, 403
Scombridæ collected near Plymouth, 226
Scopæus minimus, 507
Scophthalmus norvegicus, 234, 435–53 ; containing Trematodes, 516
Serranidæ collected near Plymouth, 222
Sibinia sodalis, 512
Sipalia testacea, 506
Siriella Clausii, 167
Sitones waterhousi, 512
Skeletonema costatum, 135–42, 170–8, 441
Slabberia halterata, 161
Smicronyx jungermanniæ, 512
Solea lascaris, 237, 443–6
— *lutea*, 237
— *variegata*, 237, 435–48 ; containing Trematodes, 514, 516
— *vulgaris*, 237, 435, 438, 443, 445 ; containing Trematodes, 514, 516
Spirodinium acutum, 194
— *concentricum*, 194
— *crassum*, 195
— *fissum*, 193
— *glaucum*, 176, 196
— *obtusum*, 194
— *spirale*, 176, 193
Squilla Desmaresti, 167
Steenstrupia rubra, 161, 175
Stenus atratulus, 507
Stomotoca dinema, 161, 171 ; containing *Anaphia petiolata*, 51 ; *Pharyngora bacillaris*, 160
Streptotheca thamensis, 135, 142, 149, 171–5
Strombidium caudatum, 138, 159
Subcoccinella (*Lasia*) 24-*punctata*, 510
Surrirella fastuosa, 152
Synchæta, sp., 164
Syngnathidæ collected near Plymouth, 215
Syngnathus acus, 456
— *rostellatus*, 215, 457, 517

T

Tachys parvulus, 500
Temora longicornis, 165–78, 435–59
Terebellid larva, 163
Thalassiosira, 136
— *condensata*, 144
— *decipiens*, 144
— *gravida*, 139, 142, 174–6, 440
— *Nordenskioldii*, 143
— *subtilis*, 144
Thalassiothrix nitzschioides, 138, 151, 459
— sp., 142, 173, 174
Thaumaleus longispinosus, 166
Tiarina fusus, 138, 158

Tintinnopsis beroidea, 158, 159, 172–7, 439
— *campanula*, 159
— sp., 178
— *ventricosa*, 158, 159, 170, 171, 437–53
Tintinnus subulatus, 159, 177
Tomopteris heligolandicus, 164
Trachinidæ collected near Plymouth, 244
Trachinus vipera, 244, 440
Trechus fulvus, 501
— *subnotatus*, 501
Trematode larva from Buccinum, 514
Trematodes in post-larval fish, 516
Trigla gurnardus, 241, 440
— *hirundo*, 241
— sp., 437, 438
Triglidæ collected near Plymouth, 241
Trochiscia Clevei, 155
Trogophlœus halophilus, 508
— *unicolor*, 508
Turris pileata, 161, 171; containing *Anaphia petiolata*, 51; *Pharyngora bacillaris*, 57, 160
Tychius schneideri, 512

W

Willsia stellata, 161

Z

Zeidæ collected near Plymouth, 229
Zeugopterus punctatus, 236, 437–52
— *unimaculatus*, 235, 437–52
Zeus faber, 229; host of *Zoogonus*, 514
Zoogonus viviparus, 514

MBL WHOI Library - Serials
5 WHSE 02416

14976